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A PHOTOGRAPHIC IMPACT TESTING MACHINE FOR MEASURING THE VARYING INTENSITY OF AN IMPULSIVE FORCE.

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INTRODUCTION.

The usual classification of variable forces as impulsive and non-impulsive depends upon their rates of change of intensity.

As ordinarily understood, an impulsive force is one whose intensity changes too rapidly to permit successive measures of it. The main object of all engineering and structural work may be said to be the supplying of adequate resistances to neutralize dangerous forces, and as this cannot be done satisfactorily until the maximum values of these forces are known, it is thought that no apology is necessary for any proposition

that promises to advance, be it ever so slightly, our capacity to measure forces.

There are two methods for such measurement, the static and the dynamic methods. The former, which is quite limited in its application, consists essentially in balancing the unknown force by a known one. The latter, which is the true scientific method, requires the accurate measurement of extremely minute intervals of time and space.

The practical measurement of forces has shown but a few applications of the dynamic method, since no apparatus possessing the required delicacy and accuracy has been available. As a direct consequence of our inability to measure impulsive forces, they are found by engineers to be the most dangerous, and our constructions are liable to show unnecessarily high factors of safety and waste of material on the one hand, or break-downs with their disastrous consequences on the other. The forces developed by blows furnish the most striking examples of impulsive forces. The engineer is compelled to measure a blow in *units of work*, although he knows that the ability of his structure to stand the blow depends upon the *maximum intensity* of the stress developed. In exceptionally favorable cases he may be able to measure the mean stress, but this is of comparatively little use to him.

This necessity for passing from units of intensity to units of work in measuring a blow has produced a great deal of confusion. It has caused the average mechanic, and even the average engineer, to think and to speak inaccurately on the subject of blows. How frequently do we hear, in discussions of applied forces, the expression, "Ah! but there we have no longer a pressure, it is a blow!" The speaker evidently thinks that a wide gulf separates a blow from a pressure. He can understand a pressure and anticipate its effect; but the mere fact that a blow is delivered is sufficient, in his mind, to account for any observed effect, and to remove the matter at once from the field of accurate, scientific discussion. This popular misconception should be removed. There is no difference between a blow and an equivalent pressure except in the matter of time. The blow produces its maximum pres-

sure in an inconceivably short interval of time, and the static testing machine cannot tell us what that maximum was. We know that the slightest variation in conditions of blow may affect largely the maximum pressure developed, and that this pressure is especially susceptible to differences in duration of blow.

When required to neutralize the effect of an impulsive force the engineer should have information on two points, viz.:

(1) He should know the maximum intensity of the force.

(2) He should know the physical qualities of resisting material *when subjected to impulsive forces.*

It is a mistake to assume that a piece of metal, or other material, will show the same effect when subjected, on the one hand, to a given force applied slowly—as in a static testing machine—and, on the other, to the same force applied and withdrawn within thousandths or tens of thousandths of a second.

Is it possible to construct a practicable impact testing machine capable of furnishing the above-described information? From the experience gained and the success attained in investigating a special problem, the writer is inclined to answer this question in the affirmative, and a description of this special investigation is thought to be the best way to place the reader in a position to judge for himself.

DYNAMIC MEASURE OF PRESSURE PRODUCED BY A BLOW.

An instrument, called the crusher gauge, is used to measure the maximum pressures developed by the expansive force of fired gunpowder. It consists, essentially, of a housing which screws into the face of the breech-block and encloses a small cylinder of pure annealed copper, half an inch long and a quarter of an inch in diameter. A hard steel piston (area one-tenth of a square inch) moves in a gas-tight channel in housing and transmits the powder pressure to copper cylinder.

The effect of the pressure is to shorten the cylinder, and the exact amount of shortening is determined in each case by micrometer measurements made before and after firing. This shortening, or compression, is translated into maximum pow-

der pressure by means of a "tarage table" constructed from static testing machine data. This data is obtained by compressing a series of similar cylinders in a static machine and recording the mean loads required to produce the successive compressions. Suppose, for example, that the static machine shows a load of 4,500 pounds to be necessary to compress the cylinder 0·2 inch, *i. e.*, to change its length from 0·5 inch to 0·3 inch. It is assumed, then, that the maximum powder pressure on piston is 4,500 pounds—45,000 pounds per square inch—when the effect of it is to produce this 0·2 inch compression in the copper cylinder.

There are many interesting details concerning the con-

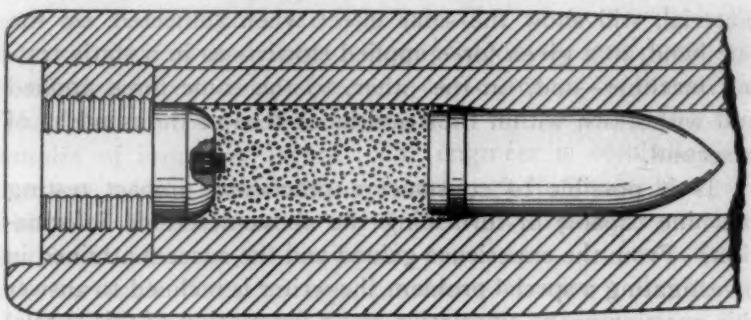

FIG. 1.

struction and use of crusher gauges that cannot be given here. It is desired only to show that the gauge furnishes an excellent example of the enforced neglect of the element of time in measuring forces. The military engineer has been compelled to assume that the compression produced in this copper cylinder by a given pressure, applied slowly in the static machine, is identical with that produced by the expansive force of powder gases, applied and withdrawn within a few thousandths of a second. Theoretically, the effects cannot be the same. To produce compression, an appreciable mass, even in the copper cylinder itself, must be moved, and this requires time.

During the spring of 1891, the writer conceived the idea of compressing this copper cylinder by means of a blow and

securing a dynamic measure of the cylinder's successive resistances.

By a proper selection of the mass and impact velocity of striking weight, any given compression can be produced in about the time consumed in producing the same compression in the gun.

Let us assume, for the present, that we have an apparatus which will record for us a curve such as is shown in *Fig. 2.*

The ordinates of this curve represent the successive shortenings of copper cylinder, during the delivery of blow, or the distances passed over by the weight after impact. The corresponding abscissas represent the times from instant of

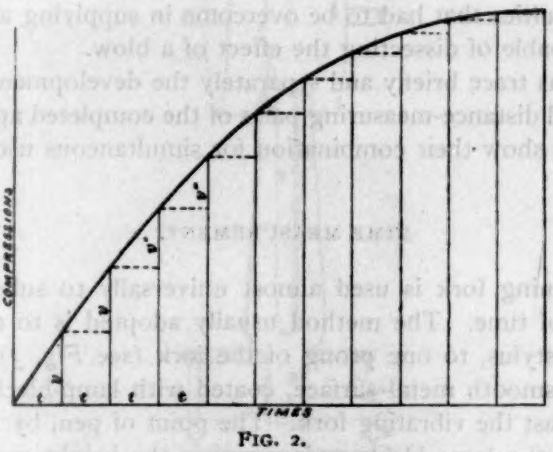

FIG. 2.

impact. The ordinates are separated by equal times, each equal to the smallest interval of time that can be accurately measured. This small interval is the unit of time, Δt, used in measuring the total duration of blow. Since this total duration is to be limited to a few thousandths of a second, it is evident that our unit of time, Δt, must be extremely minute if we are to divide the total compression into a great number of parts. The differences between the successive ordinates divided by the time, Δt, enable us to measure the successive velocities of the weight after impact. The differences of these successive velocities, divided by Δt, give us the successive

changes in weight's velocity, or the retardations due to copper resistance. The products of these retardations by the mass of weight measure the successive resistances of copper cylinder.

The process amounts simply to a graphical differentiation of the impact compression curve recorded as a function of the time of compression.

To obtain, in this way, a measure of the varying pressure produced by a blow, we must construct an apparatus capable of measuring simultaneously, and with the greatest accuracy, extremely minute intervals of time and space.

For all such measurements the first requisite is means for accurately *magnifying* the quantities to be measured. Only those who have had the experience can thoroughly appreciate the difficulties that had to be overcome in supplying an apparatus capable of dissecting the effect of a blow.

Let us trace briefly and separately the development of the time- and distance-measuring parts of the completed apparatus and then show their combination for simultaneous use.

TIME MEASUREMENT.

A tuning fork is used almost universally to subdivide a second of time. The method usually adopted is to attach a pen, or stylus, to one prong of the fork (see *Fig. 3*) and to cause a smooth metal surface, coated with lamp-black, to be drawn past the vibrating fork. The point of pen, by plowing through the lamp-black and exposing the bright metal surface, records a waving line, called a sinusoid. If the surface be drawn past while the fork is at rest, a straight line, called the median line, is produced. The width of record represents the fork's amplitude. The measured distances between the intersections of these lines show how far the recording surface moved during a whole or a half vibration of the fork. For smaller intervals of time it is usually assumed that the velocity of surface remains constant for the vibration interval.

It will be seen that the accuracy of time measurement will increase directly with:

(1) The rate of the fork—a fork that divides a second into

1,000 parts being preferable to one that divides it into only 100 parts, just as a scale showing hundredths of an inch is preferable to one showing only tenths.

(2) The velocity of recording surface. If we have 1 inch as the distance equivalent of the time of one vibration of fork, we can pass more accurately to a given fractional part of this time than we can when this distance equivalent is only one-tenth of an inch.

(3) The clearness of intersections of median line and sinusoid.

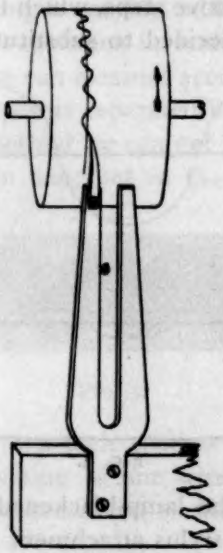

FIG. 3.

The upper record in *Fig. 4* illustrates the use of a slow fork with large amplitude. The median line and sinusoid intersect at an obtuse angle, and it is easy to fix the points of intersection. The next record illustrates the substitution of a fork twice as fast as the first one. We thus divide a second into twice as many parts, but the amplitude decreases with an increase in rate of fork, and we observe a greater chance for error in fixing the points of intersection. The same trouble would follow a doubling of the velocity in recording surface. If we continue to increase either the rate of fork or the

velocity of recording surface, we shall obtain a result illustrated by the third record, wherein great difficulty would be experienced in fixing the points of intersection.

These conditions limit us, in the stylus method, to a fork of about 500 complete vibrations per second, and to a velocity of recording surface of about 10 feet per second.

It was evident that the above-described method would not meet the conditions imposed upon the projected impact testing machine, and the writer entered, during the summer of 1891, upon the development of a new and an improved method. After successive steps, which involved a great many experiments, it was decided to substitute a sensitized photo-

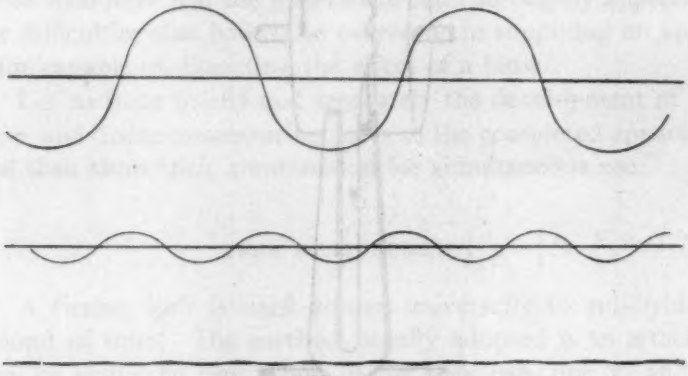

FIG. 4.

graphic surface for the lamp-blackened metal surface and a beam of light for the stylus attachment to the fork.

The resulting time scale is illustrated by *Fig. 5*.

A hole with perfectly smooth edges is bored in the end of fork and illuminated by a concentrated beam of light. A lens placed between fork and sensitized surface produces a sharp and a magnified image of the edge of this hole. As the fork vibrates, the image moves up and down on the horizontally moving surface. The diameter of circular image is greater than the horizontal distance traversed by sensitized surface during the time of one vibration of fork.

Instead of being limited to $\frac{1}{500}$ of a second, the main divisions in this scale represent less than $\frac{1}{4000}$ of a second, and

the velocity of recording surface was about 100 feet per second, instead of 10. The troublesome intersections of median line and sinusoid are here replaced by the intersections of the up-and-down curves, readily determined by causing the cross hair in microscope of measuring instrument to bisect the angle between curves. This operation is facilitated by the areas of double exposure in body of record, the points of which are directed toward these intersections.

When it is impracticable to secure uniform velocity in the recording surface—as, for example, when this surface is attached to a body having a varying motion which we wish to investigate—the main divisions in scale will be the smallest interval of time that we can measure accurately, and we should have as many sets of points separated by this interval as possible. In the stylus method we can get but two sets, since we have only one median line; but in the photographic record

FIG. 5.

we obtain two sets from each shadow line. These shadow lines are cast by a grating of fine wires, or hairs, placed in close proximity to the sensitized surface and in the path of beam of light.

A more rapid fork could be used with equal facility, and the velocity of recording surface could readily be increased to 500 feet per second. By the method to be described later, this velocity can also be kept constant for a longer time than would be consumed in delivering the blow to be investigated. The use of a high fork is made practicable by the fact that we record not the actual amplitude of fork, but the amplitude of movement in the magnified image.

Our ability to magnify the amplitude without affecting the wave lengths in time scale, and our control of the relation of diameter of image to these wave lengths, will always enable

us to cause the up-and-down curves in record to intersect at about a 45° angle, the angle most favorable to an accurate determination of these intersections. The limits, in stylus method, to rate of fork and to velocity in recording surface are removed at once, and the effect of this removal may be compared with the effect upon accuracy of distance measurement of substituting a vernier caliper for a carpenter's rule. It is not necessary to dwell upon the advantages resulting from the substitution of the smooth, sensitized, for the rough, lamp-blackened surface, nor upon the advantage of securing a record of its vibrations without requiring the fork to do the mechanical work involved in plowing through the coating of lamp-black.

With a uniform velocity of 500 feet per second in sensitized surface—and to obtain this velocity it will be necessary only to give a 12-inch cylinder 10,000 revolutions per minute —we can readily detect an interval of time as small as one-tenth of a millionth of a second.

When we begin to subdivide a second of time on the one hand, or to multiply the circumference of the earth on the other, we are unable, through absence of contrast, to appreciate through our senses the magnitudes of our results.

The smallest interval of time that photography enables us to measure is just about as much less than a second as the distance to the nearest fixed star is greater than the circumference of the earth, and yet it requires 3½ years for light from this star to reach us, the velocity of light transmission being 188,000 miles per second.

DISTANCE MEASUREMENT.

Fig. 6 illustrates the method devised to secure a magnified photographic record of the distance traversed by weight after impact, *i. e.*, the compression of copper cylinder during delivery of blow.

A hardened steel piston rests on the copper and a hardened steel plug is secured in the end of weight *W*. The downward motion of piston after impact follows the compression of copper cylinder, the diameter of piston being such as to prevent

any appreciable compression in the piston under the maximum pressure developed.

The small mirror, *m*, revolves about a fixed horizontal axis, and is connected with the piston by link work in which the journals and pivots are ground to as accurate a fit as possible.

The cylinder, *C*, is rigidly mounted at a horizontal distance in front of mirror, determined by the magnifying ratio desired, and means are provided to revolve it at great speed about a vertical axis. The surface of cylinder is covered by a photographic film, a perfect glove fit being secured; or, if desired,

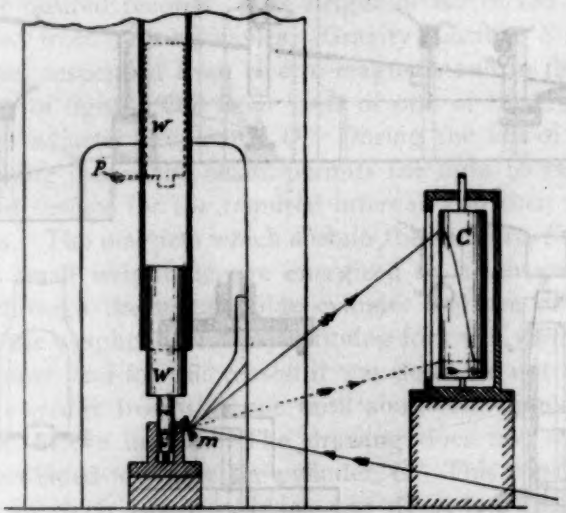

FIG. 6.

the cylinder can be made of glass, ground true, and coated as the ordinary photographic plates are coated. A beam of light, after passing through a proper combination of lenses, is thrown on the small mirror, *m*, and reflected thence to the surface of cylinder, *C*. This beam traces its path on the sensitized surface and produces a curve whose ordinates are *magnified reproductions of the downward motions of piston and hence of the successive compressions of copper cylinder.*

We thus obtain the *impact curve*, which needs only a time scale, parallel to axis of abscissas, to enable us to construct a

pressure curve for the copper specimen which will show the actual resistance offered by the copper at each stage of compression.

SIMULTANEOUS MEASUREMENT OF TIME AND DISTANCE.

The skeleton drawing, *Fig. 7*, illustrates the combined and simultaneous use of time- and distance-measuring apparatus.

The experiments are conducted in a dark room, and the

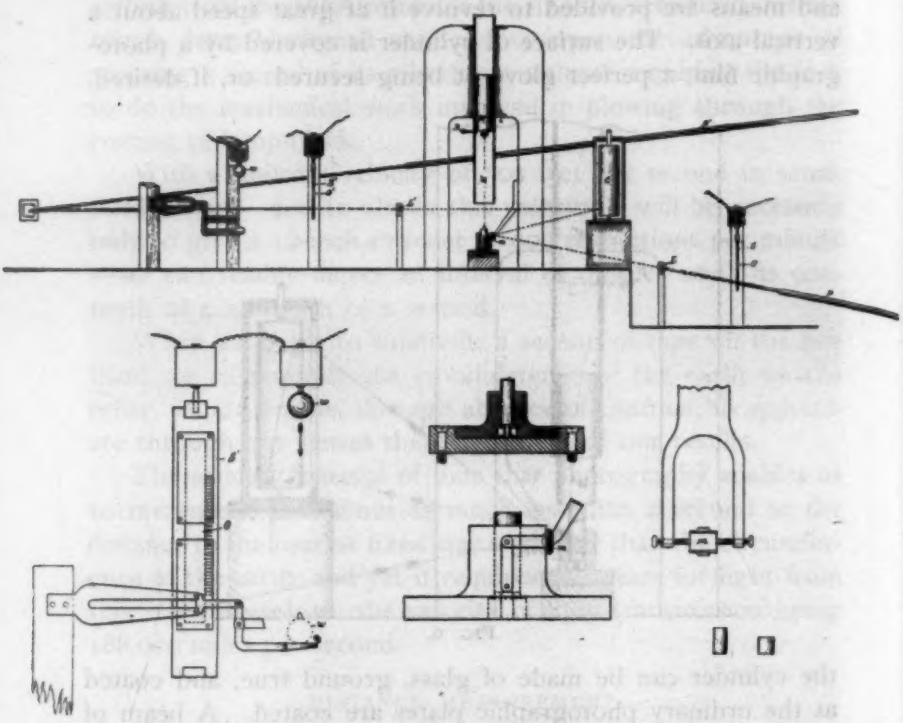

FIG. 7.

two required beams of sunlight are reflected through pipes, p and p', from outside mirrors. The tuning fork is shown with a spreading wedge inserted between its prongs, ready to be withdrawn by impact of small weight, w', on end of lever. The weight, W, which strikes the blow on copper specimen, is released by withdrawing the metal pin which sustains it in the vertical guiding tube. The lens, L, produces a small and

intense image of the sun on the surface of cylinder, *C*. This image moves upward during delivery of blow and traces the impact curve. The lens, *L'*, produces a well-defined and enlarged image of the circular edge of hole in end of fork. This image traces the required time scale parallel to axis of abscissas of impact curve. These two beams of concentrated light must not be turned on until just before impact, and they must be turned off again immediately after completion of blow. In the experiments made, the cylinder, *C*, completed about 100 revolutions per second, and it required only about one-third of one revolution to produce the desired records. The height of fall of the weight, *W*, varied from 7 to 15 inches. Gravity shutters, *S* and *S'*, are shown suspended from electro-magnets, and in the paths of beams of light. The front view of one of these shutters shows an adjustable opening, *O*. During the fall of shutter this opening passes the beam, permits the light to reach the sensitized surface for the required interval, and then shuts it off again. The magnets which sustain the shutters, *S* and *S'*, and the small weight, *w*, are energized by a current which passes through the metal guide cylinder and the pin which sustains the weight, *W*. A rapid tuning fork will vibrate only a short time, and for this reason it was desirable not to withdraw the wedge from this one until about one-hundredth of a second before impact. The drawing does not show the means provided to rotate the cylinder, *C*. This consisted, at first, of an electric motor, which was discarded because the varying wave lengths in time scale showed that the rotation of cylinder was not as uniform as was desirable. The motor was then replaced by a system of multiplying cog wheels and a drum, the cord from drum passing to an auxiliary falling weight of about 100 pounds. The end of cord was not fastened to drum, so that, when unwound, the cord was entirely disconnected, and the cylinder was left with its maximum speed to be gradually reduced by friction.

The auxiliary weight was used to operate an adjustable trigger, which withdrew the metal pin, *P*, and released the weight, *W*, at a time such that impact of *W* on copper speci-

men occurred just as the cord became disconnected from drum. By this means the impact curve was recorded at the instant that acceleration in speed of cylinder, *C*, was passing through zero, and at this stage it was impossible to detect any variation in surface velocity. The frictional resistances being small, we should expect the rotation of cylinder, under these circumstances, to remain constant for the interval of time—not over 0·004 second—consumed in delivering the blow.

We can now trace the operation of this delicate mechanism.

After careful micrometer measurements of its length and its diameter, the copper cylinder is placed in position with the hard steel piston resting on it. The weight, *W*, is adjusted for the desired fall, which we will represent by *H*. The slides, *S* and *S'*, are suspended and adjusted so that the distance of lower edge of opening, *O*, above upper edge of beam of light, is less than *H* by a few hundredths of an inch, the exact difference being accurately calculated. A similar adjustment is made for the fall of small weight, *w*. The sensitized covering is placed over cylinder, *C*, and the wedge inserted between prongs of tuning fork. Assistants, outside the dark room, keep the reflected beams adjusted.

The apparatus is now ready to work automatically. The operator releases the auxiliary weight (not shown in drawing) and the cord which is attached to this weight begins to unwind from drum. The rotation of cylinder, *C*, communicated from the drum through multiplying cog-wheels, increases rapidly. When the auxiliary weight has fallen a determined distance it operates a trigger and pulls out the pin, *P*. The withdrawal of this pin releases the weight, *W*, and breaks the electric current, so that the shutters, *S* and *S'* and the small weight, *w*, begin to fall. A few thousandths of a second before *W* strikes its blow, acceleration of cylinder speed is stopped by disconnection of cord from drum, the weight, *w*, by its action on lever pulls out the wedge and sets the fork vibrating; the opening, *O*, in shutter *S*, is opposite its beam of light and the image of sun formed by this beam, after reflection from rotating mirror (which is now stationary, since impact has not yet oc-

curred) begins to trace the axis of abscissas of impact curve; the opening in shutter, *S*, permits a simultaneous appearance of the vibrating image of hole in fork to appear just under the sun image, on same vertical element of cylinder, where it begins to trace a refined time scale.

When impact occurs, the copper specimen yields under the pressure developed; the hard steel piston follows up this yielding; the small mirror revolves at a rate depending entirely upon movement of piston, and the sun image moves upward in a vertical plane, reproducing, on a magnified scale, the successive compressions of copper specimen. The resistance to compression offered by the copper, working over the path of compression, gradually absorbs the kinetic energy in weight, *W*, and reduces the velocity to zero. A wave of elastic compression in copper precedes the permanent set. This elastic recovery is observed, in the static testing machine, to be practically constant and equal to about 0·002 inch. It causes the weight, *W*, to rebound, and, after second impact, to rebound again a lesser distance, and so on until it is finally brought to rest, supported on the steel piston. These secondary blows do not increase the permanent set in copper specimen, and they should not, since their impact energies can never be greater than the work in elastic compression, wherein is found the source of the rebounds.

An observer, standing in the dark room and looking toward the revolving cylinder, sees on its surface, at the instant of impact, a brilliant vertical line of light whose duration is less than that of a flash of lightning. The photographic film on the rapidly-spinning cylinder, however, has secured, during this inconceivably short interval of time, a permanent record of many important events and arranged them in chronological order, to be examined and studied at our leisure.

Fig. 8 shows a reduced reproduction of one of the impact curves.

In this case a 33·109-pound weight fell 15 inches and produced a permanent compression of 0·1658 inch in copper specimen. The time consumed in producing this compression was 0·0030317 second.

USE OF IMPACT CURVE.

To make the impact curve, *Fig. 8*, available for calculating a table to give the resistance, in pounds, for any given compression of copper cylinder in inches, it is necessary to know the rate of fork and the relation between any given ordinate of the curve and the compression of specimen. Photography was used to obtain this information, but space does not per-

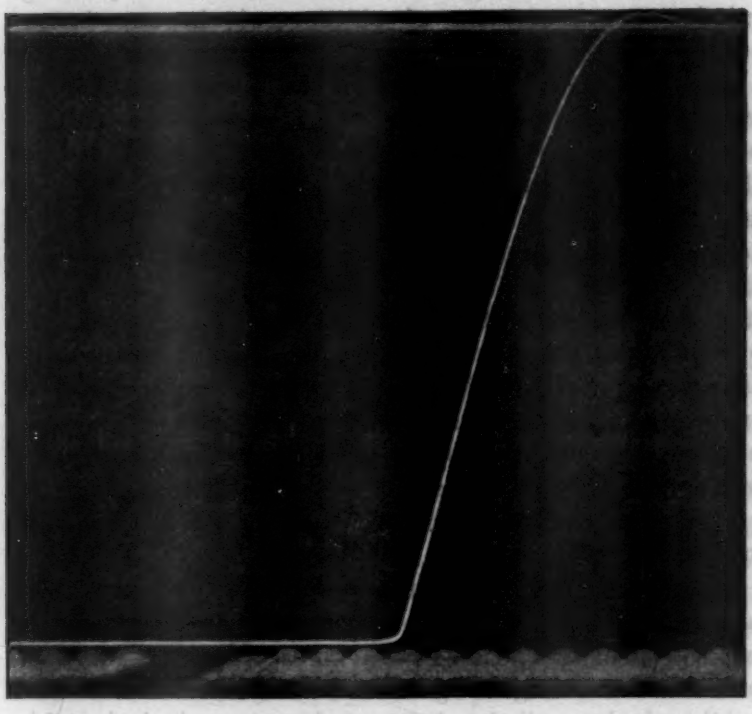

FIG. 8.

mit a detailed description* of methods adopted. The fork was calibrated by securing its record on a long photographic plate falling freely under action of gravity, and the variable ratio of ordinate to compression was determined from a series of "scale negatives" made by moving the piston down one-thou-

*Detailed descriptions are given in "Notes on the Construction of Ordnance, No. 71, Government Printing Office, Washington, D. C.

sandth of an inch at a time and recording photographically the corresponding positions of "sun image."

With an instrument reading accurately to 0·00001 meter, a number of sets of ordinates, the individual ordinates in each set being separated by a constant and a small interval of time, Δt, were then measured and tabulated. The first differences of these ordinates measure the rate of compression, or velocity of falling weight after impact, and a curve can be constructed

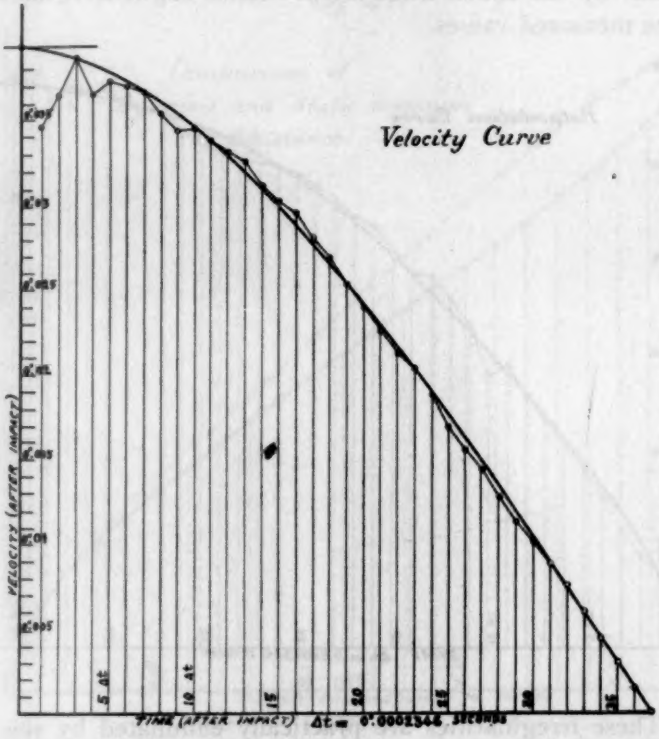

FIG. 9.

showing this velocity as a function of either time or compression. Each "set" of ordinates gives a "set"of points in this curve, and it is evident that we may obtain as many points as desired.

Fig. 9 shows a velocity curve constructed in this way for one of the negatives.

This curve was plotted on a very large scale, and the mean curve, assumed to be the true one, was easily drawn.

The true impact velocity and the initial tangent to curve are known from the height of fall of the weight, *W*.

The steel piston is at rest at the instant of impact, and requires some time to acquire the velocity of *W*. For this reason the initial measured velocities of piston are lower than the theoretical velocities of *W*, and the vibrations produced in apparatus by the shock from impact cause slight irregularities in the measured values.

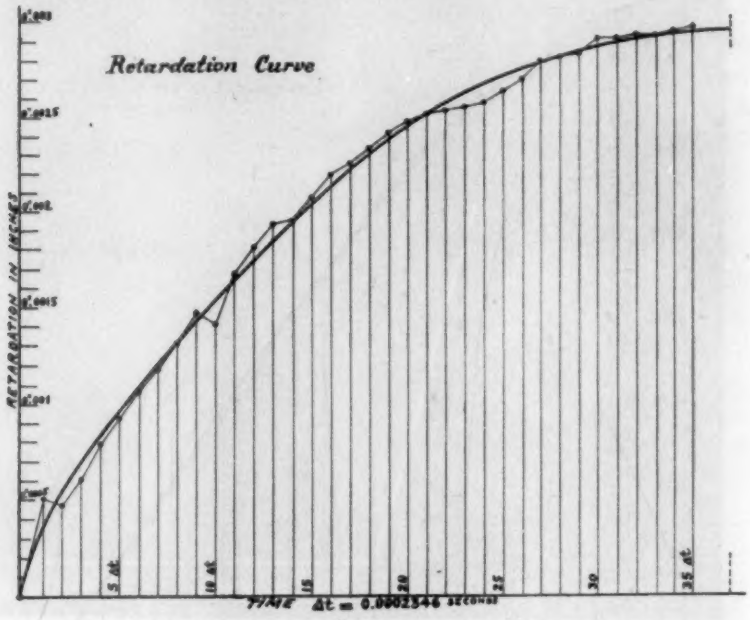

FIG. 10.

These irregularities are practically eliminated by the adjusted curve, and they do not appear during the final stages of compression. Since our main object is to obtain a reliable dynamic measure of the *maximum* resistance of specimen, the slight irregularities in measured data for the earlier stages are of little consequence.

After adjusting our tabulated "first differences" by the mean velocity curve, *Fig. 9*, we form another table showing

"second differences" as a function of time, and use these data to plot the "retardation curve," *Fig. 10.* We know the initial and terminal tangents to the true retardation curve, and can readily draw the mean curve.

The analytical expression for the resistance, R, which, working over the path of compression, C, absorbs the kinetic energy in weight, W, is

$$R = -\left[\frac{W}{g}\frac{d^2c}{dt^2} + W\right]$$

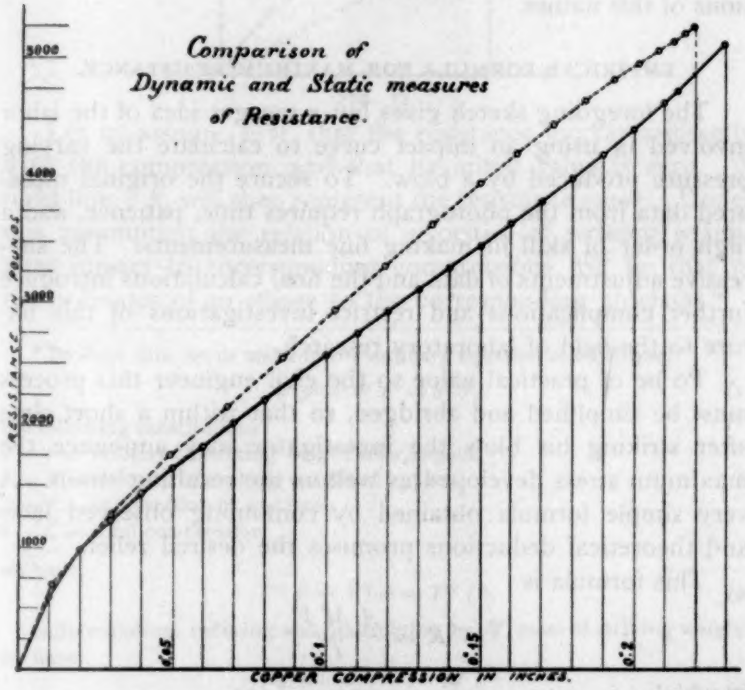

FIG. 11.

The ordinates of the retardation curve, *Fig. 10*, represent the variable factor

$$\frac{a^2c}{dt^2}$$

By plotting, as a function of the compression, the values of R, obtained in this way, we obtain the dynamic resistance curve shown broken in *Fig. 11.*

For comparison, the same figure shows the resistance curve obtained from static testing machine data.

The difference between them represents the effect of the neglected "time element" or the error of "static tarage" when the total time consumed in producing the compression is about 0·003 second. This error will vary with the time, and it should also vary largely with the mass of specimen. The civil engineer who uses massive pieces to sustain impulsive forces is, therefore, interested in a further pursuit of investigations of this nature.

EMPIRICAL FORMULA FOR MAXIMUM RESISTANCE.

The foregoing sketch gives but a meager idea of the labor involved in using an impact curve to calculate the varying pressure produced by a blow. To secure the original measured data from the photograph requires time, patience, and a high order of skill in making fine measurements. The successive adjustments of data and the final calculations introduce further complications and restrict investigations of this nature to the field of laboratory research.

To be of practical value to the civil engineer this process must be simplified and abridged, so that within a short time after striking his blow the investigator may announce the maximum stress developed as well as the resulting strain. A very simple formula obtained by combining observed facts and theoretical deductions promises the desired relief.

This formula is

$$R = \frac{A\,M\,V}{T}$$

in which

R = maximum stress developed in a rigidly supported specimen by a blow.

$M\,V$ = quantity of motion in striking mass at instant of impact.

T = total duration of blow.

A = a coefficient whose limiting values are

1·57+

and unity. The value of this coefficient for a given blow will depend upon T and the material of specimen.

A brief outline of the study which furnished this formula is necessary to a thorough understanding of its utility.

In *Fig. 12* let the ordinates be resistances and the abscissas compressions.

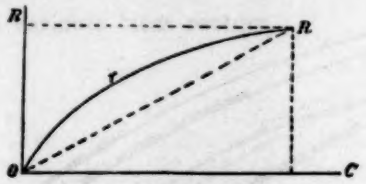

FIG. 12.

Let us assume, first, that the resistance increases directly with the compression, and that its initial value is zero. A right line, $o\,R$, will then represent the resistance curve. Under this assumption the relation of velocities of striking weight after impact to corresponding compressions will be that of the ordinates of an ellipse to the corresponding abscissas.*

---

*To show this, let us make in the ordinary equation of an ellipse,

$$a^2 y^2 + b^2 x^2 = a^2 b^2, \qquad (1)$$

the following substitutions:

$y = v =$ velocity of striking weight after impact.

$b = V =$ velocity of striking weight at impact.

$x = c =$ compression of specimen.

$a = C =$ total compression,

we have,

$$C^2 v^2 + V^2 c^2 = V^2 C^2. \qquad (2)$$

Differentiating, reducing and multiplying by M, mass of striking weight, we have:

$$M \frac{v\,d\,v}{d\,c} = R'' = -\frac{M\,V^2}{C^2}\,c. \qquad (3)$$

Equation (3) shows that the resistance, R'', increases directly with the compression, c.

For the second assumption we substitute in the parabola equation,

$$y^2 = 2\,p\,x,$$

v for y, $C - c$ for x, $\frac{V^2}{C}$ for $2\,p$, and obtain for R' the constant value,

$$R = \frac{M\,v\,d\,v}{d\,c} = -\frac{M\,V^2}{2\,C} \qquad (4)$$

On the other hand, let us assume the resistance as constant. A right line, such as *R R*, parallel to axis of compressions, will then represent the resistance curve, and the relation of velocities to compressions will be that of the ordinates of a parabola to the corresponding abscissas.

The middle curve in *Fig. 13* is the adjusted velocity curve

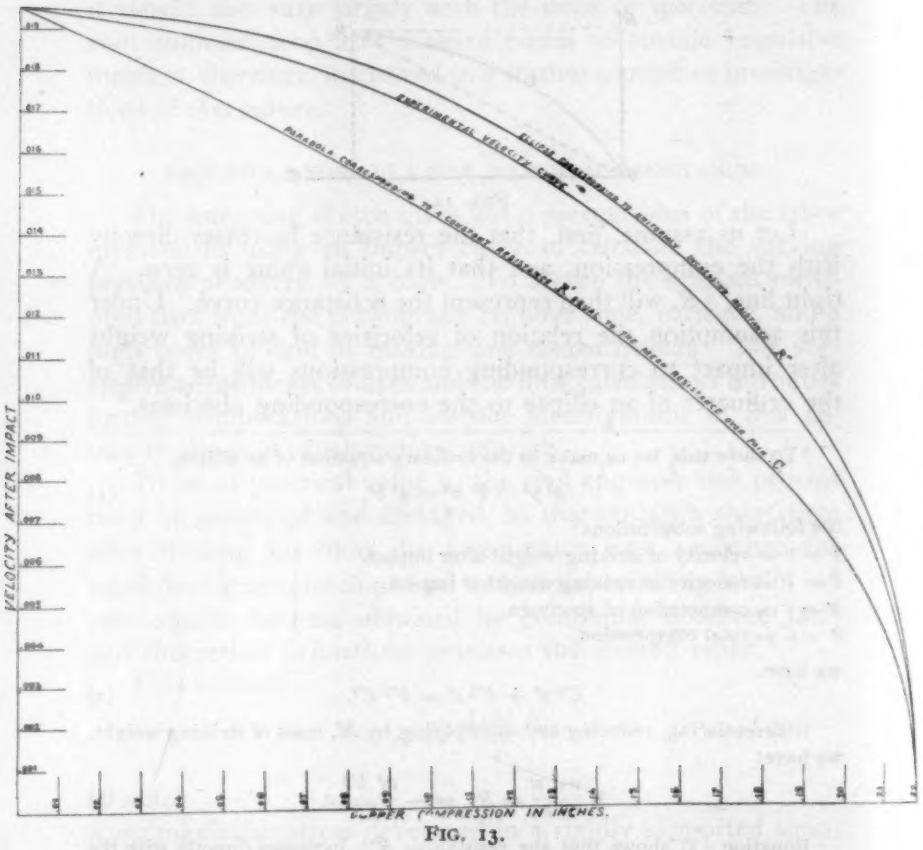

FIG. 13.

of negative No. 22, plotted accurately as a function of compression. The upper curve is an ellipse, and the lower one is a parabola, both constructed to pass through the initial and final points of the true velocity curve.

Since the true velocity curve, *Fig. 13*, lies between the ellipse and the parabola, we see that the true resistance curve

will be some such curve as *O r R*, *Fig. 12*, and that the right lines, *o R* and *R R*, corresponding respectively to the ellipse and to the parabola, *Fig. 13*, will be the limits.

The equation of the impact curve, as a whole, has not been determined. It can be represented by the equation,

$$t^2 = x\, c,$$

a parabola with a variable latus rectum.

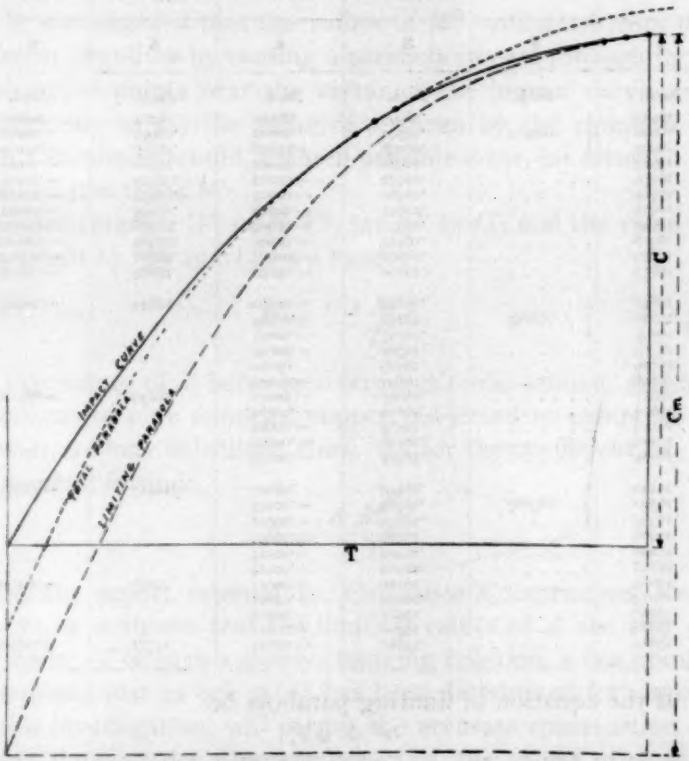

FIG. 14.

By selecting three points in impact curve, each separated by $\Delta\ t$, we can cause a parabola to pass through them and have its axes parallel to axes of impact curve.

Fig. 14 shows two such parabolas.

That parabola whose axis coincides with the maximum ordinate of impact curve is called the limiting parabola.

The following table shows that in the vicinity of the three selected points a parabola passing through them may be taken to represent the impact curve. The columns headed $\Delta c'$ and $\Delta c''$ show the differences between corresponding ordinates.

Measured Compressions.	Mean Compressions.	Trial Parabola. $i^2 = (5{\cdot}6207762 - 10)\,c$.		Limiting Parabola. $i^2 = (5{\cdot}6006113 - 10)\,c$.	
		$0{\cdot}16995 - c'$	$\Delta c'$	$0{\cdot}16995 - c''$	$\Delta c''$
1	2	3	4	5	6
Inch.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
·16995	·169923	·16995	·00000	·16995	·00000
·16992		·16992	·00000	·16992	·00000
·16990		·16998	+·00008	·16987	—·00003
·16983		·16981	—·00002	·16980	—·00003
·16974		·16972	—·00002	·16970	—·00004
·16965		·16960	—·00005	·16959	—·00006
·16955		·16947	—·00008	·16944	—·00011
·16940		·16931	—·00009	·16928	—·00012
·16918		·16913	—·00005	·16909	—·00009
·16899		·16892	—·00007	·16887	—·00012
·16872		·16870	—·00002	·16864	—·00008
·16847	·168223	·16849	+·00002	·16842	—·00005
·16826		·16822	—·00004		
·16794		·16793	—·00001		
·16763		·16762	—·00001		
·16729		·16729	·00000		
·16698		·16693	—·00005		
·16657		·16655	—·00002	·16639	—·00018
·16619		·16615	—·00004		
·16575		·16573	—·00002		
·16529		·16528	—·00001		
·16484		·16481	—·00003		
·16440	·163887	·16440	·00000	·16413	—·00027
·16392		·16389	—·00003		
·16334		·16335	+·00001		
·16276		·16280	+·00004		
·16208		·16222	+·00014		
·16148		·16162	+·00014		
·16089		·16100	+·00011	·16057	—·00032
·16034		·16035	+·00001		
·15957		·15969	+·00012		
·15886		·15900	+·00012		
·15814		·15802	—·00014	·15773	—·00041

If the equation of limiting parabola be

$$i^2 = a\,c, \tag{1}$$

the value of maximum resistance, R (neglecting gravity), will be

$$R = \frac{M\,d^2\,c}{d\,t^2} = \frac{2\,M}{a} \tag{2}$$

By substituting in (1) T, total duration of blow, for t, and calling the resulting value of c, $C\,m$, we have

$$C\,m = \frac{T^2}{a} \tag{3}$$

The work, W', that the constant force, R, equation (2), is capable of performing during the time T is

$$W' = R\,C\,m \tag{4}$$

The actual work, W, done during the time, T, by the resistance of specimen is

$$W = \frac{M\,V^2}{2} \tag{5}$$

It was *observed* that the values of W'—obtained from the different negatives by causing a parabola to pass through three consecutive points near the vertex of the impact curve, and substituting in (4) the value of a, given by the equation of such a parabola—could, without sensible error, be assumed as equal to just twice W.

Substituting $2\,W$, or $M\,V^2$, for W' in (4) and the value of $C\,m$ given by (2) and (3), we have

$$R = \frac{\sqrt{2}\,M\,V}{T} \tag{6}$$

For values of T between 0·003 and 0·004 second, and for specimens of pure annealed copper, subjected to compressive stresses, we may substitute, then, $\sqrt{2}$ for the coefficient, A, in the general formula,

$$R = \frac{A\,M\,V}{T}$$

In the report referred to, Ordnance Construction Note No. 71, it is shown that the limiting values of A are 1·57 + and unity. For such a slowly changing function, a few points, determined just as one point has been determined for copper by this investigation, will permit the accurate construction of curves showing, for different materials, the values of A as a function of T.

With tables constructed from these curves, it will be necessary, in testing a given specimen, to measure only the value of T. A table will give the value of A, the known mass and height of fall of striking weight will give the product $M\,V$, and the maximum resistance, R, can be stated shortly after delivery of blow. An impact curve will not be necessary in practical

testing, since micrometer measurements before and after the blow will show the effect on specimen. The apparatus herein described will then be simplified and will become a chronograph pure and simple. The interval of time to be measured, T, is readily connected with the making and breaking of an electric current. With the striking weight as one pole, and the specimen, or piston resting on it, as another, the current will be made at the instant of impact and broken by rebound.

The foundation for any accurate chronograph must be a refined time scale, such as had to be provided for this investigation. As soon as this time scale was obtained, it was seen that a photochronograph for general use, especially in ordnance work, was available. It remained only to provide means for causing light signals to mark the beginning and the ending of the time interval to be measured. The simplest and most economical device for this purpose was the Ruhmkorf

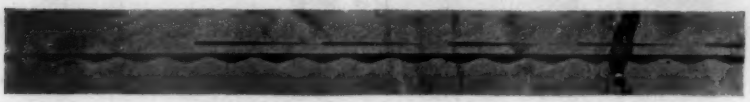

FIG. 15.

induction coil, and in 1891-92 a chronograph was designed by the writer and constructed by the Ordnance Department, U. S. Army, wherein the secondary sparks were photographed simultaneously with the time scale and gave the desired signals.

Fig. 15 is a reproduction of a record from this chronograph, which shows the times occupied by a projectile in passing over successive intervals of 2 feet.

A theoretical objection to the use of the Ruhmkorf coil is found in the fact that the secondary spark is not produced simultaneously with the break in primary circuit; but when we require *two successive* sparks and have a uniform time scale, even the slight errors due to this delayed action can be made to balance each other.

Fig. 16 reproduces another chronograph record, wherein the duration of secondary spark is made practically instanta-

neous and a fine shadow line is placed in each spark record. These shadow lines are of great assistance in obtaining accurate measurements from the photographs.

Some years after the construction of this photochronograph, two other investigators, working independently of the writer, produced an instrument involving a new method of securing the light signals.*

This highly ingenious and original method reduces materially the delayed action above mentioned, but it does not seem possible to procure with it the well-defined limits for use in measuring, given by shadow lines in spark records, *Fig. 16.*

With chronographs available for measuring T with the required accuracy, the outlook for a practicable and a reliable "Impact Testing Machine" seems promising.

FIG. 16.

One other possible simplification remains to be mentioned. It will be remarked that in the general formula for R,

$$R = A\frac{M}{T}V$$

the second factor expresses the *mean resistance* of specimen. Another expression for this mean resistance is obtained by dividing the *energy* in striking mass by the *path.*

It may be found more convenient and more expeditious to measure the *path* rather than the *time.* In this case it will be necessary to determine A as a function of the height of fall of striking mass. This may or may not be possible. If so, the use of photography, and the consequent complications and delays—due to necessity for operating in a dark room, to time required for development, etc.—may be avoided.

* See article on "Polarizing Photo-Chronograph," by Doctor Crehore and Lieutenant Squier, U. S. Army, in *Journal of the United States Artillery*, Vol. VI, No. 3.

CONCLUSION.

The measurement of intensities of impulsive forces is of general interest to the scientific world and of special interest to the engineering profession.

It is suggested that in some thoroughly equipped laboratory an extension of the investigation herein described should be made.

AN ATTEMPT AT A SYNTHETICAL DEMONSTRATION OF THE PRIMARY PROBLEMS OF THE DIFFERENTIAL CALCULUS.

BY DAVID WALTER BROWN, PH.D.

I attempt in the following paper to demonstrate the primary problems of the differential calculus by a method of direct synthetical reasoning, as distinguished from the somewhat indirect method of infinitesimals and limiting ratios. The demonstration proceeds upon the application of simple laws of proportion to variable quantities.

In the discussion the usual sign $\int$ for a function is retained. The meaning of the new signs for the *rate of change*, the *rate-ratio*, and the *variable multiplier* will be explained in the proper place.

A *variable quantity* (or simply, *variable*) is one whose magnitude changes; a *constant quantity* (or simply, *constant*) is one whose magnitude does not change.

I designate the rapidity of the change of a quantity by the term *rate of change* (or more simply, *change-rate*), and indicate it by the letter C (which is the initial of "change") written before the symbol for the quantity.

Thus $C\ x$ signifies the change-rate of x; $C\ y$ the change-rate of y, and so on.

When the hypothesis assumes that the change-rate of a variable does not depend upon the change-rate of any other quantity, then the variable is called *an independent variable*. When the change-rate of the variable depends upon the

change-rate of some other quantity, the variable is called a *function* of that other quantity.

Properly speaking, the *change-rate* is not a quantity, although it has commensurable magnitude. It is only a property of a quantity, analogous to the velocity of a moving body, and similar to the fluxion of Sir Isaac Newton. I think the change-rate of a quantity can no more be considered a quantity, in the sense its variable is a quantity, than the color or velocity of a body can be considered the body to which it pertains.

The magnitude of the change-rate is not arbitrary in any problem. It is fixed once for all by the hypothesis of the problem itself, and can not be increased or decreased in the discussion of that problem. Its magnitude, moreover, is not dependent upon the instantaneous magnitude of its variable, but may be many times greater than the magnitude of the variable. In those cases where the magnitude of the change-rate is a constant, as hypothesis assumes it to be in the case of independent variables, the change-rate remains unchanged through all the changes of the variable, and is the same when the magnitude of the variable is zero as when it is infinitely great.

In considering the proportional effect produced upon the magnitude of a function by the changing magnitude of a variable, it becomes evident that this effect can not be due solely and entirely to the magnitude of the change-rate of the variable, but is due to the proportion which the magnitude of the change-rate bears to the simultaneous magnitude of the variable, since this proportion expresses the proportion or ratio in which the magnitude of the variable is changing under the influence of the change-rate, and that the development of this proportion must influence the development of the proportional change of the magnitude of the function.

I term this ratio of the magnitude of the change-rate to the simultaneous magnitude of its variable, the *rate-ratio*, and indicate it by the letter R written before the variable. Thus $R\,x$ signifies the rate-ratio of x; $R\,y$ the rate-ratio of y, etc.

Since the rate-ratio of a variable is the proportion which the

magnitude of the change-rate bears to the simultaneous magnitude of its variable, the rate-ratio is equal to the quotient obtained by dividing the magnitude of the change-rate by the simultaneous magnitude of the variable. Or, since the symbols for the variable, the function, and the change-rate convey to the mind the notion of instantaneous magnitude, we may say more briefly and simply, the rate-ratio is the quotient of the change-rate divided by its variable. Therefore, in a similar manner we may say that the change-rate is the product of the rate-ratio multiplied by its variable, and the variable is the quotient of the change-rate divided by the rate-ratio.

Or in symbols

$$R\,x = \frac{C\,x}{x} \tag{1}$$

$$C\,x = (R\,x)\,x \tag{2}$$

$$x = \frac{C\,x}{R\,x} \tag{3}^*$$

Since the rate-ratio is the proportion at which, at any instant, the magnitude of a variable quantity is changing, and since this proportion is equal to the magnitude of the change-rate divided by the simultaneous magnitude of the variable, the rate-ratio of any variable quantity goes through a development which depends upon the changing proportion between the simultaneous magnitudes of the change-rate and its variable. In the case of a constant change-rate the law of the development of the rate-ratio follows the changes of the magnitude of the quotient of a constant quantity divided by a variable quantity whose magnitude is changing according to an arithmetical series. In those cases, however, when the change-rate is variable, the law of development of the rate-ratio follows the change of magnitude of a fraction whose numerator and denominator are both changing according to certain laws. Generally, however, in determining the primary laws of the calculus, we are relieved from particularly considering the law of development of the rate-ratio. We only observe the instantaneous value of the ratio, and mentally make a note of the fact that it is developing according to some law, whatever that law may be.

*Equation 3 is a general equation of integration.

We also observe that the expression for the magnitude of the rate-ratio,

$$\frac{C\,x}{x}$$

is universal, since it clearly allows for any development of the change-rate, or of the variable, or of both.

THE MEANING OF EQUALITY IN THE CALCULUS.

In general, when our hypothesis leads us to assume that any two quantities are equal, in reasoning on the calculus, the idea of equality has a two-fold significance: (1) that the magnitudes of the two quantities are equal at the instant of our observation; (2) that they remain equal throughout the entire development of those quantities. Thus, if we express such an hypothesis by the symbols $x=y$, we perceive that this equation signifies both that x and y are equal at the instant of our observation, and that they remain equal throughout their entire development. And this proposition is universally true, when comparing variables, functions, and the ratios of variables and functions. Thus, if we have the equality expressed by the symbols

$$\int z = \int x\,;\; y = a\,x\,;\; xy = z\,;\; x : y = s$$

etc., in every case the relation of equality continues throughout the entire development of the variable, or function, or ratio in question, and we perceive that the equality of constant quantities is but a special case of the general law.

In the reasoning of the calculus there is but one exception, if it be an exception, viz.: that after the analysis of the relations of the change-rate has been completed we may, in order to ascertain the momentary values of equations, make the variable equal to some constant quantity. But in this case we are no longer dealing with the laws of development of the change-rate, but only with the momentary effect produced by those laws.

Let us now examine some of the consequences of this law of equality. Suppose we are considering the case where a

variable is equal to the product of some other variable by a constant, expressed in symbols by

$$y = a\,x$$

This immediately gives us the proportion

$$1 : a :: x : y$$

But since the ratio $1 : a$ is a *constant* by hypothesis, the ratio $x : y$ must also be a *constant*, ever equal to the ratio $1 : a$. But this is only possible when x and y are simultaneously increasing or decreasing in the same proportion of their own simultaneous magnitudes, and when the increase or decrease of both follows the same law of development. For, in any other case, the ratio of the magnitude of x to the simultaneous magnitude of y would change during the development of the two quantities.

It therefore follows that the rate-ratio of y is the same as the rate-ratio of x, and we perceive the truth of this principle of the calculus:

I. The rate-ratio of the product of a variable by a constant is the same as the rate-ratio of the variable.

Expressed in symbols,

$$R\,y = R\,a\,x = R\,x = \frac{C\,x}{x} \qquad (4)$$

Since the change-rate of y equals the rate-ratio thereof multiplied by y, we have

$$C\,y = y\,(R\,y) = y\left(\frac{C\,x}{x}\right) = a\,x\left(\frac{C\,x}{x}\right) = a\,C\,x \qquad (5)$$

and we have established this proposition:

II. The change-rate of the product of a variable by a constant is equal to the change-rate of the variable multiplied by the constant.

Evidently we may now assume that any variable is the product of a constant whose magnitude is equal to the simultaneous magnitude of its variable, multiplied by a variable whose original magnitude is unity, and whose rate-ratio is the same as the rate-ratio of the first named variable. I indicate this unity variable by the sign for unity (1) with the symbol of the variable out of which it is derived in each case written as a sub-index. Thus we may write $x = a\,(1_x)$, where $a = x$,

and the symbol (1_x) indicates a variable whose magnitude, at the instant of our observation, is unity, and whose rate-ratio is the same as that of x. Similarly we may write

$$y = b\,(1_y);\ z = c\,(1_z), \text{ etc.}$$

But the magnitude of the change-rate of (1_x) is equal to the magnitude of the rate-ratio multiplied by the simultaneous magnitude of the variable, and, therefore, the change-rate of (1_x) is equal to the rate-ratio thereof multiplied by unity. Consequently the rate-ratio and the change-rate of the unity variable are equal each to each.

In symbols

$$C\,(1_x) = 1\,.\,R\,(1_x) = \frac{C\,x}{x}$$

I call this unity (1_x) variable the *variable multiplier*, because it is the variable multiplier of the constant factor of the variable whose effects on a function we are considering. Certain of the conditions which arise in the discussion of the relations of the rate ratios of variables are more clearly explained by resorting to the use of it, than in any other manner.

Consider next the ratio of two quantities, and first of constants of equal magnitude. Evidently that ratio is unity and a constant. In symbols $a : a = 1$.

Consider next the ratio of a constant to a variable, which has momentarily the same magnitude as the constant. Evidently the momentary value of the ratio is unity, but the ratio is not now a constant.

Expressed in symbols the ratio is

$$a : x$$

We can put $x = a\,(1_x)$, and the ratio may be expressed

$$a : a\,(1_x)$$

Assume we started with two constants, a, a, the ratio having been

$$a : a = 1$$

Manifestly we have multiplied the consequent by the variable (1_x), and since the antecedent remains unchanged, the ratio must be multiplied by the same variable, becoming $1\,(1_x)$, and we perceive at once that the ratio is now a variable, and has the same rate-ratio as x.

The same principle would also immediately appear upon considering the fraction

$$\frac{x}{a} \text{ or } \frac{a\,(1_x)}{a}$$

It is then axiomatic that the magnitude of the fraction is increasing in the same proportion of itself as the numerator is simultaneously increasing in a proportion of itself, and that the rate-ratio of the fraction must follow the same law of development as the rate-ratio of the numerator. Also, since the rate-ratio of a variable multiplied by a constant is the same as the rate-ratio of x, the rate-ratio of

$$\frac{b}{a}x$$

must be equal to the rate-ratio of x, and therefore the foregoing principles are universal, and we perceive these two propositions to be true:

III. The ratio of a constant to a variable has the same rate-ratio as the variable.

IV. The rate-ratio of a variable divided by a constant is the same as the rate-ratio of the variable.

Proposition IV also follows from proposition I. For if a variable is equal to the quotient of another variable divided by a constant, then the second variable must be equal to the product of the first variable multiplied by the constant, and this is the case of proposition I. Or in symbols, if

$$x = \frac{y}{a}$$

then must $y = a\,x$, and by proposition I, $R\,y = R\,x$.

But the change-rate is equal to the rate-ratio multiplied by its variable. Therefore, in symbols, for brevity, if

$$x = \frac{y}{a}, \text{ and } R\,x = R\,y$$

$$\text{then} \qquad C\,x = (R\,x)\,x = (R\,y)\frac{y}{a} = \left(\frac{C\,y}{y}\right).\frac{y}{a} = \frac{C\,y}{a} \tag{6}$$

and we have established this proposition:

V. The change-rate of the quotient of a variable divided

by a constant, is equal to the quotient obtained by dividing the change-rate by the constant.

Consider now the case of the quotient of two variables which are originally equal and have equal rate-ratios, that is, are each simultaneously increasing in the same proportion of their contemporaneous magnitudes. This quotient is manifestly unity and a constant. Or, in symbols,

$$\frac{x}{x} = 1$$

Now, suppose that, without changing its instantaneous magnitude, we increase the rate-ratio of the numerator of this fraction, by causing the numerator to increase in a greater ratio of its own magnitude than before; or, in other words of equivalent meaning, suppose that, without changing the instantaneous magnitude of the numerator, we cause it to increase more rapidly than before, by adding to its original rate-ratio some additional ratio. Evidently the numerator, with this new development of its rate-ratio, is increasing more rapidly than before, and evidently also, from the assumed conditions of its new increase, its magnitude, under the influence of the new ratio, is outstripping the simultaneous development of its old magnitude, as that proceeded under the old ratio, in exactly the ratio which was added to the old ratio. That is to say, the ratio between the simultaneous values of its old and its new magnitudes has now become a variable, instantaneously equal to unity, and increasing in the proportion of the added ratio. But the magnitude of the denominator of the fraction is, by hypothesis, equal to the original magnitude of the numerator, and the denominator also has the same rate-ratio as the numerator originally had. Therefore the magnitude of the numerator, with its new development, is outstripping the simultaneous magnitude of the denominator in exactly the same proportion as we have seen it is outstripping the development of its old magnitude as produced by its original rate-ratio. Therefore, the fraction

$$\frac{x'}{x}$$

has now become a variable; — x' representing the new development of the numerator—and we may write

$$\frac{x'}{x} = z$$

where the instantaneous magnitude of z is unity, and its rate-ratio is that which was added to the original development of the numerator. It follows, therefore, that the present rate-ratio of the numerator is equal to the original rate-ratio thereof (which is by hypothesis the same as the rate-ratio of the denominator) plus the rate-ratio of z. Or in symbols

$$R\,x' = R\,x + R\,z \qquad (7)$$

But the equation

$$\frac{x'}{x} = z$$

gives us $x' = z\,x$, and we perceive that, in this case, the rate-ratio of x' is equal to the sum of the rate-ratios of the two variables of which x' is the product. Therefore this proposition is true:

When the magnitude of a variable is instantaneously equal to unity, the rate-ratio of the product of that variable by another variable is the sum of the rate-ratios of the variables taken separately.

But since we know, from proposition I, that the rate-ratio of any product of a variable by a constant is the same as the rate-ratio of the variable, so that we have

$$R\,(a\,x) = R\,x;\ R\,(b\,x') = R\,x';\ R\,(c\,z) = R\,z$$

whatever the magnitudes of the constants may be, we perceive the foregoing principle to be universal, and we arrive at this proposition:

VI. The rate-ratio of the product of two variables is the sum of the rate-ratios of those variables taken separately.

In symbols we have, when $z = x\,y$,

$$R\,z = R\,x + R\,y \qquad (8)$$

Therefore

$$C\,z = (R\,z)\,z = (R\,x + R\,y)\,x\,y$$

and

$$C\,z = \left(\frac{C\,x}{x} + \frac{C\,y}{y}\right) x\,y = y\,C\,x + x\,C\,y \qquad (9)$$

That is to say:

VII. The change-rate of the product of two variables is equal to the sum of the products of each variable by the change-rate of the other.

For the case of x^2, where x and y become equal, this resolves to

$$x\,Cx + x\,Cx = 2\,x\,Cx \tag{10}$$

Suppose we have to consider the rate-ratio of the product of the three variables, x, y, z.

Plainly we may let the product of x by y be equal to s, and then we have

$$R(sz) = Rs + Rz$$

But

$$Rs = Rx + Ry$$

so that finally we get

$$R(x.y.z) = Rx + Ry + Rz \tag{11}$$

and we perceive the general law:

VIII. The rate-ratio of the product of any number of variables is the sum of the rate-ratios of those variables taken separately.

Suppose $s = x, y, z$

Then

$$Rs = Rx + Ry + Rz$$

and

$$Cs = \left(\frac{Cx}{x} + \frac{Cy}{y} + \frac{Cz}{z}\right) xyz = yz\,Cx + xz\,Cy + xy\,Cz \tag{12}$$

That is:

IX. The change-rate of the product of any number of variables is equal to the sum of the products obtained by multiplying the change-rate of each variable by all the other variables.

This leads directly to the proposition that

$$Cx^n = n\,x^{n-1}\,Cx \tag{13}$$

That is,

X. The change-rate of any power of a variable is equal to the product obtained by multiplying the change-rate by the

variable raised to a power one less than its original power, and this product multiplied by the exponent of the power.

Consider next the ratio $x : a$.

Evidently if the antecedent is increasing in any proportion of itself, while the consequent remains constant, the ratio is decreasing in the same proportion of itself, and the proportionate change of the antecedent and of the ratio must follow the same law. But since the ratio is decreasing while the antecedent is increasing, the change of the ratio must be expressed as negative, and therefore we find in this case that the ratio is a variable quantity, changing in the same proportion as the antecedent, but negatively. Hence the rate-ratio of the ratio is $-Rx$. But this is the same case as

$$\frac{a}{x}$$

and we perceive that—

XI. The rate-ratio of a constant quantity divided by a variable is the rate-ratio of the variable with the opposite sign.

In symbols,

$$R\left(\frac{a}{x}\right) = -Rx \tag{14}$$

But,

$$C\left(\frac{a}{x}\right) = R\left(\frac{a}{x}\right)\frac{a}{x} = -\left(Rx\right)\frac{a}{x} = -\frac{Cx}{x}\cdot\frac{a}{x} = -\frac{aCx}{x^2} \tag{15}$$

That is,

XII. The change-rate of a constant divided by a variable at the first power is equal to the quotient obtained by dividing the product of the constant into the change-rate of the variable by the square of the variable, and this quotient having the opposite sign from that of the change-rate of the variable.

We could also deduce propositions XI and XII from proposition VI. For since $Rxy = Rx + Ry$, then, when $xy = a$, we have $Rx + Ry = O$, whence $Rx = -Ry$, and consequently, if Rx be positive, Ry must have the same expression for magnitude, but with the negative sign.

But

$$C\left(\frac{a}{x}\right) = C\,y = (R\,y)\,y = (-R\,x)\,y\,. = -\frac{C\,x}{x}\cdot\frac{a}{x} =$$

$$-\frac{a\,C\,x}{x^2}\,*$$

Let us next consider the case of a function which is equal to a variable plus a constant. Evidently the change-rate of such a function is solely and entirely due to the change-rate of the variable, and cannot be effected by the constant. Therefore the change-rate of such function must be the change-rate of the variable. Or, in symbols, if $y = a + x$, then $C\,y = C\,x$.

We reach the same conclusion from consideration of the rate-ratio of such a function. For, evidently, the rate-ratio thereof, that is the proportion of its own magnitude at which the function is changing, cannot now be the same as the rate-ratio of the variable, but must be to the rate-ratio of the variable in the inverse proportion of the magnitudes of the variable and the function. Or, in symbols,

$$R\,(a + x) : R\,x :: x : a + x$$

Whence we have

$$R\,(a + x) = \frac{(R\,x)\,x}{a + x} = \frac{C\,x}{a + x}$$

Consequently the change-rate of

$$a + x = R\,(a + x)\,.\,a + x$$

which equals

$$\left(\frac{C\,x}{a + x}\right)(a + x) = C\,x \qquad (16)$$

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* By a simple application of proposition VI, we shall find that the change-rate of the quotient of a constant divided by any power of a variable,

$$\left(\text{in symbols, } \frac{a}{x^n}\right)$$

is equal to the product of the change-rate of the variable into the constant, into the exponent of the power, divided by the variable raised to a power one greater than its original power, and this quotient having the minus sign. Or,

$$\left(\text{in symbols, } C\left(\frac{a}{x^n}\right) = -\frac{n\,a\,C\,x}{x^{n+1}}\right)$$

Similar reasoning proves that the change-rate of a variable less a constant is the same as the change-rate of the variable. Or, in symbols, $C(x - a) = C x$.

Thus we have established this proposition:

XIII. The change-rate of a variable increased or diminished by a constant is the same as the change-rate of the variable.

Let us next consider the case of the sum of two variables.

When the variables are such that one may be regarded as the function of the other, we may write $y = a x$. So that the sum of $x + y$ becomes $x(1 + a)$. But we know from previous principles that the rate-ratio of this quantity is equal to the rate-ratio of x. Let us express the relations in symbols,

$$R(x(1 + a) = R x$$

But the change-rate of a variable is equal to the rate-ratio thereof multiplied by the variable. That is,

$$C(x(1 + a) = R(x(1 + a)(x(1 + a) = R x(x(1 + a) =$$

$$\frac{C x}{x}(x(1 + a) = C x + a C x \qquad (17)$$

But since $y = a x$, $a C x$ is the change-rate of y, and we have:

XIV. The change-rate of the sum of two variables is the sum of the change-rates of the variables.

When, however, one of the variables is not a function of the other, the same law still holds true. For, in the case of the sum of two such variables, we observe we have the condition of the independent developments of the change-rates and the rate-ratios of two variables, each development unaffected by the other, and, as a necessary consequence, the total effect of the two developments must be the sum of the effects separately due to each. We thus have presented the case of a quantity made up of two independent parts, each of which is changing in some proportion of its own magnitude, unaffected by and unaffecting the change of the other part. In such circumstances, it is evident that the proportional change of the whole, due to the proportional change of either part, must be to the proportional change of that part in the inverse ratio of the

magnitudes of the whole and the part. This gives us, as the expression for the proportional change of the whole, due to the proportional change of x,

$$R\,x\left(\frac{x}{x+y}\right)$$

and similarly as to y,

$$R\,y\left(\frac{y}{x+y}\right)$$

Therefore the rate-ratio of the whole is

$$R\,(x+y)=\frac{x(R\,x)+y\,(R\,y)}{x+y}$$

whence the change-rate of $x+y$ is found, thus

$$C(x+y)=R\,(x+y)(x+y)=\left(\frac{x(R\,x)+y\,(R\,y)}{x+y}\right)(x+y)=$$
$$C\,x+C\,y \qquad (18)$$

The foregoing principles enable us to determine expressions for the change-rate of any product, quotient, power or root of a variable, or of the sum or difference, product or quotient of any combination of variables, or of the power or root of such combination.

It is now manifest that the relations of the change-rate of a variable to the change-rate of its functions are the same as those commonly said to exist between the differential of a variable and the differentials of its functions. But the method of change-rates and rate-ratios here developed has a certain logical superiority over the method of the differential, as usually treated.

In the first place, the primary definition of the change of magnitude of a variable as due to a rate of change, which is analogous to the velocity of a moving body, is a definition which corresponds to the fact. The development of a variable quantity is comparable to a ceaseless flow, but it is not comparable to a broken step-by-step change, such as the usual method of infinitesimals necessarily assumes it to be.

Again the method of rates of change is logically consistent

in defining the rate of change to be only a property of a quantity, possessing commensurable magnitude, but not itself a quantity—no more so than is the velocity of a moving body the body to which it pertains.

Finally, by insisting that the magnitude of the rate of change is not arbitrary in any problem, but is once for all fixed by the primary hypothesis of that problem, this method conforms the development of the variable through its functions to the well-known facts often presented in the concrete problems, particularly of engineering, to which the calculus is applied; in which it is logically impossible to suppose the magnitude of the rate of change to be other than the concrete conditions show it necessarily is.

The treatment of the development of a variable quantity as due to another quantity whose magnitude is arbitrary and may therefore be made infinitesimal, involves the logical fallacy that since we are unable to derive the relations of the differential from the finite magnitude assigned to it by the hypothesis of our concrete problem, we may change that magnitude to an infinitesimal magnitude, and then, having reached a limiting ratio, for the case when the differential is infinitesimal, assume, without positive proof, that ratio holds true when the differential has the assigned finite magnitude, although the operations by which we arrive at the limiting ratio cannot be performed in the case when the differential has a finite magnitude. The mind may accept the conclusion, but it objects to the logic of the method.

The method of the change-rate is a return to the conception of the great inventor of fluxions, and avoids the logical difficulties which inhere in the treatment of the differential as an arbitrary quantity.

THE MAXIMA AND MINIMA OF FUNCTIONS.

It has been my purpose to demonstrate the primary problems of the differential calculus, not to apply the solutions of those problems.

But the harmony of the conceptions of the change-rate and the rate-ratio with the elementary conditions of the maxima and minima of functions deserves notice.

At the instant of the maximum or minimum of a function, the differential of the function is said to be zero.

But since a differential is an infinitesimal quantity, by the usual hypothesis, and smaller than any assignable magnitude, it is not easy, upon merely logical grounds, to perceive why, at the instant of the maximum or minimum of the function, its differential need be any smaller than it always has been, nor why the limit of this quantity should not just coincide with the maximum or minimum; and the statement that the magnitude of the differential is zero at the minimum or maximum therefore becomes unnecessary and without significance.

But again, in concrete problems connected with areas of curves and like subjects, the differential is assumed to be an infinitely thin strip or lamina of the surface or solid under consideration. But if this be so, then upon no logical grounds whatever can it be shown that the division between two adjacent laminæ does not occur exactly at the minimum or maximum; but if the division between two adjacent laminæ does occur at the maximum or minimum, then there is no greater propriety in saying that the differential is zero at those points, than in saying it is zero at the indefinite number of other points where such a division occurs.

But when we once perceive that the variation of the magnitude of a function is due to a change-rate, and that if, as the function is approaching the maximum, its change-rate is positive, because it is then increasing the magnitude of the function, and if, as the function passes the maximum, its change-rate becomes negative, because it is then decreasing the magnitude of the function, it follows as a necessity of logical thinking that a positive rate can become a negative rate only by becoming zero at the instant of its change from positive to negative, and the principle becomes axiomatic that—

At the maximum or minimum of a function its change-rate is zero.

Now, the rate-ratio offers us the means of determining whether a given value for a variable, deduced by making the change-rate of the function zero, is a maximum or a minimum; for,

When a function is passing through the maximum, the sign of its rate-ratio changes to the opposite sign from that of the function; and when the function is passing through the minimum the sign of its rate-ratio changes to the same sign as that of the function.

This proposition is deduced from the following considerations:

At the instant of the maximum, the function has a certain magnitude (assume it to be positive). As the function passes the maximum, its magnitude cannot at once pass from positive to negative, nor can it become instantly equal to zero. For the law of the development of every variable and function is that of ceaseless, unbroken flow, which is inconsistent with either of the foregoing suppositions.

Therefore, for a certain range of development beyond the maximum, the function remains positive, but its change-rate has become negative at the instant of passing through the maximum. Therefore the rate-ratio, which is the quotient of the change-rate divided by the function, became negative as the function passed through the maximum.

For the case of the minimum, suppose the function to have a positive value, but the least possible: Upon the grounds above stated, and yet more clearly, the function remains positive as it passes the minimum. But the change-rate became positive at the instant of passing through the minimum, and therefore the sign of the rate-ratio became positive as the function passed through the minimum.

If the function is considered negative at the instant of the minimum, it will be found that the rate-ratio will become negative as the function passes through the minimum, and conversely in the case of passing through the maximum.

To apply the foregoing principles to simple cases. Suppose we are required to divide a line into two such parts that the rectangle erected on the parts of the line shall be a maximum. If the line be a, and x be one part, $a - x$ will be the other part, and $a\,x - x^2$ will be the rectangle. Since this is to be a maximum, we have

$$C\,(a\,x - x^2) = o$$

whence

$$a\,C\,x - 2\,x\,C\,x = 0$$

and

$$a = 2\,x$$

whence

$$a = \frac{1}{2}\,x$$

Now construct the rate-ratio,

$$R(a\,x - x^2) = \frac{C(a\,x - x^2)}{a\,x - x^2} = \frac{C\,x\,(a - 2\,x)}{a\,x - x^2}$$

Observation shows us:

That the magnitude of the denominator remains positive even when x becomes greater than

$$\frac{1}{2}\,a$$

but that the numerator becomes negative when x increases beyond

$$\frac{1}{2}\,a$$

because then $a - 2\,x$ becomes negative. Therefore, as the function passes the value assigned to it when

$$x = \frac{1}{2}\,a$$

the sign of the rate-ratio becomes negative, and we know that the value

$$x = \frac{1}{2}\,a$$

gives a maximum value to the function.

Suppose we have a given area h, which is to be arranged into a rectangle such that the perimeter shall be a minimum.

If one side of the rectangle is x, the adjacent side is

$$\frac{h}{x}$$

and the perimeter becomes

$$2x + \frac{2h}{x}$$

But since this is to be a minimum, we have

$$C\left(2x + \frac{2h}{x}\right) = o, \text{ whence } 2Cx - \frac{2hCx}{x^2} = O$$

Whence,

$$2x^2 - 2h = o, \text{ and } x = \sqrt{h}$$

Again construct the rate-ratio

$$\frac{Cx\left(\frac{2x^2 - 2h}{x^2}\right)}{\frac{2x^2 + 2h}{x}}$$

which is equal to

$$\frac{Cx(2x^2 - 2h)}{x(2x^2 + 2h)}$$

Observation shows us that when x becomes greater than $\sqrt{h}$, the numerator and the denominator of this fraction will both be positive, and we therefore know that the value $x = \sqrt{h}$ is that which makes the function a minimum.

NEW YORK, MARCH 13, 1897.

CHEMICAL SECTION.

(*Stated meeting, Tuesday, September 21, 1897.*)

DR. LEE K. FRANKEL, Vice-President, in the chair.

THE UPPER SCHUYLKILL RIVER.

BY OSCAR C. S. CARTER,
Professor of Geology and Mineralogy, Central High School, Philadelphia.

This river, which furnishes a water supply to Philadelphia and several towns along its banks, rises in the coal regions, in the northeastern part of Schuylkill County, Pa., nearly 100 miles from Philadelphia. It flows southwest, then changes to

southeast, and then enters Berks County by a gap in the North Mountain at Port Clinton. It then flows southeast through the Great Limestone Valley and cuts through the South Mountain at the city of Reading. After leaving Berks County, it forms the boundary between Montgomery and Chester Counties, where it flows through the New Red Sandstone. It then enters the belt of older gneissic and micaceous rocks and flows southeast through Philadelphia County to the Delaware River.

Its general direction from the time it enters the gap in the North Mountain at Port Clinton until it enters the gap in the South Mountain at Reading is south 10° east; it then changes its course to south 50° east, being deflected by the spurs of the South Mountain and by meeting the New Red Sandstone. It continues in this general direction to Philadelphia.

Elevation above Tide.—The general elevation of the Schuylkill and its tributaries at their source in the coal regions is about 800 feet higher than Philadelphia at the mouth of the river. In fact, the elevation of some of the towns near its source in Schuylkill County is over 1,200 feet. Mahanoy City is 1,240 feet; Pottsville is 611 feet, and Tamaqua, near the Little Schuylkill River, is 800 feet. These elevations are above mean tide at Philadelphia. The measurements given by the Schuylkill Navigation Company show that the fall of the river is as follows:

From Pottsville to Port Clinton, a distance of 15 miles, the river descends 204 feet = 14 feet fall per mile.

From Port Clinton to Reading, a distance of 20 miles, the river descends 202 feet = 10 feet fall per mile.

From Reading to Norristown, a distance of 41 miles, the river descends 141 feet = 3½ feet per mile.

From Norristown to Philadelphia, a distance of 17 miles, the river descends 61 feet = 3½ feet fall per mile.

Acidity of the Schuylkill above Reading.—The Schuylkill River, above the city of Reading, is so strongly charged with sulphuric acid and sulphate of iron that it cannot be used as a water supply for Reading and the towns along its banks between Reading and the coal regions. We refer now to

the Schuylkill, and do not include the Maiden and Tulpehocken Creeks, both of which empty into the river near Reading. Water of this kind would strongly corrode iron boilers, so that it cannot safely be used for the generation of steam. Its effect on the fauna of the Schuylkill is strongly marked. There are practically no fish in the river between Reading and Tamaqua, which is situated on the Little Schuylkill, or, more strictly speaking, between Maiden Creek, which is 8 miles above Reading and Tamaqua. A few suckers find their way above Reading as far as Maiden Creek, but above this no black bass, perch or chub are found. Molluscan life, which is provided with a protective shell of carbonate of lime, does not flourish in this acid water; their shells would be corroded and slowly dissolved. Mussels, water snails and cray fish find more congenial quarters in the Lower Schuylkill below Reading, where the water has lost its acidity.

It is well known that the acidity of the Schuylkill is due to impurities found in coal. Coal generally contains sulphur in two forms, as pyrite, or sulphide of iron (FeS_2), and sometimes as an organic compound of sulphur, which has not as yet been studied. When iron sulphide oxidizes on exposure to air, or water containing dissolved oxygen, it begins to disintegrate, and is finally converted into sulphuric acid and sulphate of iron, both of which are soluble in water. The pyrite is the principal source of sulphur in coal; in many specimens of coal and coaly slate, these glistening yellow specks are plainly visible. Every sample of coal analyzed contains some sulphur.

Acid Water from Collieries.—The following analyses were made by W. J. Williams, and show clearly the amount of free sulphuric acid and soluble sulphates that are found in water pumped from coal mines. The Lee Colliery is not on the Schuylkill Watershed. It is situated on the Susquehanna. Both of these waters, however, are typical mine waters of the Pennsylvania coal regions. The large amount of lime and magnesia sulphates in these waters is caused by the action of the free sulphuric acid on the rocks in and near the mines:

READING COAL AND IRON COMPANY. WATER FROM ELLEN GOWAN COLLIERY.

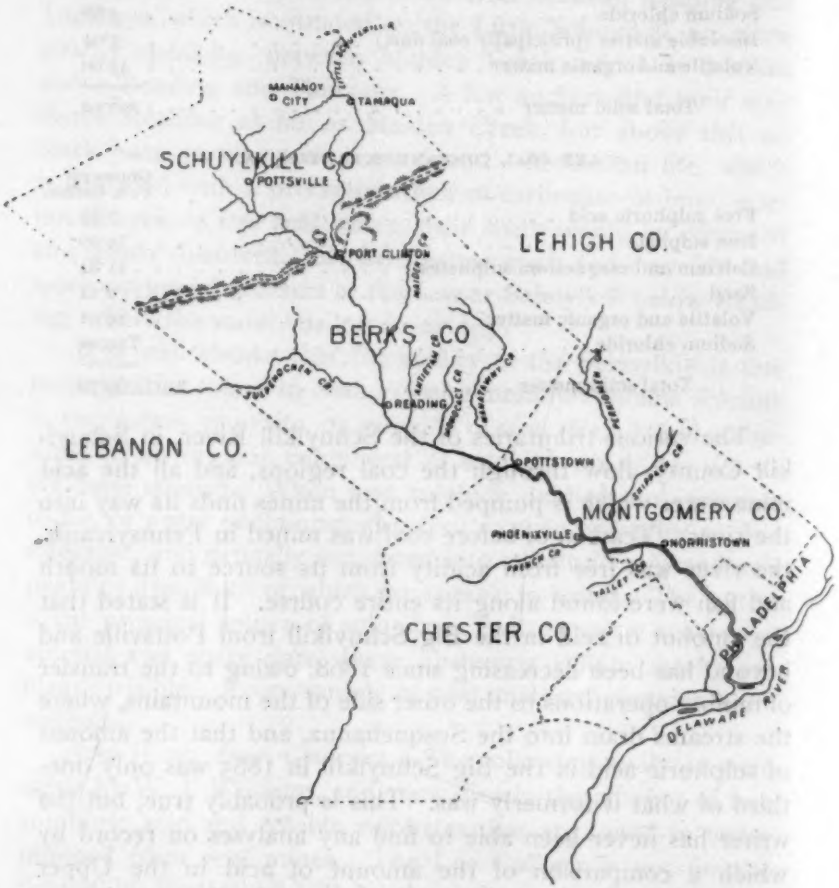
	Grains per U. S. Gallon.
Free sulphuric acid	19·60
Iron and aluminum sulphates	140·23
Calcium sulphate	45·75
Magnesium sulphate	39·72
Sodium chloride	4·68
Insoluble matter (principally coal dust)	5·04
Volatile and organic matter	43·00
Total solid matter	298·02

LEE COAL COMPANY, SCRANTON, PA.

	Grains per U. S. Gallon.
Free sulphuric acid	7·53
Iron sulphate	19·20
Calcium and magnesium sulphates	21·84
Sand	2·12
Volatile and organic matter	19·01
Sodium chloride	Traces
Total solid matter	69·70

The various tributaries of the Schuylkill River, in Schuylkill County, flow through the coal regions, and all the acid mine water which is pumped from the mines finds its way into the river. Years ago, before coal was mined in Pennsylvania, the river was free from acidity from its source to its mouth and fish were found along its entire course. It is stated that the amount of acid in the Big Schuylkill from Pottsville and beyond has been decreasing since 1868, owing to the transfer of mining operations to the other side of the mountains, where the streams drain into the Susquehanna, and that the amount of sulphuric acid in the Big Schuylkill in 1885 was only one-third of what it formerly was. This is probably true, but the writer has never been able to find any analyses on record by which a comparison of the amount of acid in the Upper Schuylkill could be made. While a great number of analyses have been made of the water in the Lower Schuylkill, but few, if any, complete analyses of the upper river are accessible. There seemed to be no necessity for such work, on account of its well-known unfitness for drinking purposes. The stream which furnishes the most sulphuric acid and sulphate of iron to

the river is undoubtedly the Little Schuylkill. In the region of Tamaqua no fish can exist, and the stones in and along the river are colored brown from the precipitated iron in the form of ferric hydrate. On account of the decrease of acid in the Big Schuylkill beyond Pottsville a few hardy catfish have



found their way up the river probably during some season of freshet when the water was strongly diluted and rendered comparatively fresh. A few of these fish are found between Port Clinton and Pottsville, but no others. These fish are not found in the river lower down between Port Clinton and

Reading, because the Little Schuylkill discharges its acid waters into the river at Port Clinton.

How the Acidity is Destroyed.—Those unacquainted with the Schuylkill might suppose that this strongly acid water from the coal regions might reach Philadelphia and affect the water supply. Such, however, is not the case. Even the towns of Phœnixville and Pottstown are unaffected by it in the slightest degree. The water loses its acid character in the vicinity of Reading, and a short distance below that city the neutralization is complete. This is due to the fact that two important streams of hard water, the Maiden and Tulpehocken Creeks, flow through the limestone country and empty into the river near and at the city of Reading. The carbonate of lime, which they hold in solution completely, neutralizes the sulphuric acid and sulphate of iron in the water. In this double decomposition which takes place, two precipitates are thrown down, namely, sulphate of lime and carbonate of iron. The reaction is as follows:

$$CaCO_3 + H_2SO_4 = CaSO_4 + H_2O + 2CO_2$$
$$CO_2$$

$$CaCO_3 + FeSO_4 = CaSO_4 + FeCO_3 + CO_2.$$
$$CO_2$$

The carbonate of iron being a very unstable salt, soon oxidizes to $Fe_2(OH)_6$, ferric hydrate, and this brown stain of iron rust is often seen on the dam at Reading when the water is low. From the bridge at Reading, when the water is not muddy or turbid from coal dust, this white precipitate of sulphate of lime can clearly be seen.

The Tulpehocken and Wyamissing empty their limestone water into the river near this point, and the precipitated sulphate of lime renders the water almost milky in appearance, especially when an excess of acid water has been pumped from the mines. This salt of lime is slightly soluble in water, and a certain amount is dissolved. This accounts for most of the sulphate of lime in Schuylkill water, which analyses show is always present between Philadelphia and Reading.

Limestone Streams Emptying into the Schuylkill.—The principal branches of the Schuylkill which flow through limestone districts and whose waters are more or less hard, are the Maiden, Tulpehocken, Wyamissing, Monocacy, Manatawny and Valley Creeks.

Maiden Creek is about 25 miles long. It rises in Lehigh County and flows over the formation known as Hudson River Shale and Utica Slate. It enters Berks County and flows over the same formation. It is fed from the slopes and foothills of the North Mountain. Finally, it reaches the Great Limestone Valley, through which it flows for a distance of 8 miles. Analysis shows that the temporary hardness is 7, and that it contains 4·08 grains of carbonate of lime per gallon. Calculation shows that every million gallons of water that flows over the bed of Maiden Creek contains 571 pounds of carbonate of lime in solution, which helps to neutralize the acidity of the main river. Then again, pebbles and particles of limestone dust, loosened by erosion, are carried by the current into the river and their action on the acid water is the same.

Tulpehocken Creek rises in Lebanon County and flows east through about 5 miles of the Great Limestone Valley. It enters Berks County and follows the limestone valley for another 5 miles, then leaves the valley and flows north and then east through the Hudson River Shale. It finally crosses the limestone valley again and empties into the Schuylkill at Reading. This creek flows through limestone for a distance of about 15 miles. When the geology of the river is well understood, it will be interesting to know why the Tulpehocken did not take a short cut and follow the limestone valley along its entire course instead of flowing north through the Hudson River Shale. It seems to go out of its natural course. Perhaps all of the valley was not eroded sufficiently deep at that time.

Wyamissing Creek is a small creek which flows through about 3 miles of the Great Limestone Valley and empties into the river at Reading.

Monocacy Creek is another small stream which flows

through about 3 miles of limestone, and the rest of the way through shale and gneiss. It empties into the Schuylkill a short distance below Reading.

Manatawny Creek rises in the gneiss, and flows south through about 8 miles of limestone country; the rest of its course is through the New Red Sandstone. It empties into the river at Pottstown.

These are the limestone streams of the Upper Schuylkill, and were it not for them, the acid water would reach Philadelphia and affect our water supply. It is not likely that the limestone of the Plymouth and Chester Valleys, which crosses the river between Norristown and Conshohocken, would completely neutralize it, because the bed of the river is covered with mud. The Tulpehocken and Maiden Creeks furnish the greatest volume of limestone water and prevent the acid water from getting below Reading.

Fish Perish in 1882.—In order to prove that the water supply of towns along the Lower Schuylkill would be affected if this acid water from the mines were not neutralized, it is only necessary to remember the summer of 1882, when so many fish perished along the river. Between Reading and Pottstown hundreds of dead fish were observed floating in the river. Many were noticed as far south as Perkiomen Creek. The Philadelphia newspapers devoted columns to it, as it was feared the water supply of the city would be affected. The cause was due to the opening of several abandoned coal mines, and the excess of acid water was pumped into the river. This unusual supply was more than the limestone streams could neutralize during the low-water season, in consequence of which the acid water passed far below the city of Reading.

Water Supply of Reading.—On account of the acidity of the Schuylkill at Reading, that city has utilized Maiden and Antietam Creeks as a water supply. These creeks are not near the coal regions, and they furnish an abundant supply of water. The following analysis of the water of Maiden Creek, made by Prof. A. R. Leeds and furnished by the Mayor, will exhibit its purity:

	Parts in 100,000.	Grains per Gallon.
Free ammonia	0·002	0·0012
Albuminoid ammonia	0·0043	0·0025
Oxygen required to oxidize organic matter	0·101	0·058
Nitrites	0·007	0·004
Chlorine	0·35	0·20
Total hardness	8·50	4·96
Permanent hardness	1·50	0·88
Temporary hardness	7·00	4·08

The report states that the quantities of free and albuminoid ammonia and nitrites are so small as not to need comment. They indicate but little drainage contamination. The water is somewhat hard, the temporary hardness being greater than the permanent hardness, which shows more carbonate than sulphate of lime. The hardness, in fact, is mainly due to the carbonate of lime.

Antietam Creek.—The other source of Reading's water supply is a mountain stream, which empties into the Schuylkill, about 4 miles below Reading. It is formed by the union of three mountain streams that have their origin in the high granitic or gneissic hills of Alsace Township. Water draining hills of gneiss is always soft. At the junction of these three mountain streams a reservoir was built, known as Antietam or Ohlinger Lake. The water is piped from the lake to Reading, a distance of about 3¾ miles. There are also two large springs which flow directly into the pipes; they are known as Hampden and Edelman Springs. The water of Antietam Lake was analyzed in 1896, by Prof. Leeds, with the following results:

	Parts in 100,000.	Grains per Gallon.
Free ammonia	0·005	0·0029
Albuminoid ammonia	0·042	0·025
Oxygen required to oxidize organic matter	0·449	0·26
Nitrites	0·008	0·0005
Chlorine	0·20	0·12

He states: "The albuminoid ammonia is ten times greater than that contained in the samples from Maiden Creek, and several times greater than is ever found in water of unquestionable purity. It amounts to the enormous figure of 0·042

parts per 100,000, and points to the presence of much matter derived from the drainage of manurial and sewage material into the water of the lake."

Bacteriological Investigation.—Prof. Leeds' remarks and the analyses of Reading's water supply are interesting as well as instructive, and it may not be amiss to quote them, as they contain some facts of general interest.

"The first step was to count the entire number of colonies of bacteria of all kinds contained in each sample of water.

COLONIES OF BACTERIA PER CUBIC CENTIMETER.

	Colonies.
South side of Maiden Creek	550
North side of Maiden Creek	440
Intake of Antietam Lake	1,200

"These figures tell us the number of bacteria, but nothing as to their nature, nor do they conclusively point to the presence of dangerous contamination. But it may be said that, as a general rule, surface waters which are entirely satisfactory contain from about 50 to 200 colonies of bacteria per cubic centimeter. When examined in March, 1894, the sample from Maiden Creek contained 50 colonies. At this present date, 1896, both samples contain a larger number of bacteria from Maiden Creek than was expected, judging from the results in 1894 and from the analysis of the water; but later on I shall show that these large numbers have not the damaging significance as at the first glance they appear to have. The mere counting of the relative numbers of bacteria in equal volumes of the water is a simple task compared with that of determining the species to which these multitudes of bacteria belong, and whether any of these species belong to the disease-producing varieties, the so-called pathogenic bacteria.

"In the present instance I was more especially charged to look for and report upon the presence or absence of the bacillus of typhoid fever in each of the four waters. To ascertain these facts a large number of cultures and hundreds of microscopic examinations, prosecuted without cessation and extending over the past interval of ten days, had to be made. The sample from the north side of Maiden Creek contained

the fewest species. They belonged almost entirely to the kinds of bacteria which are always found in natural running waters. When water comes from very deep wells, it should contain very few or no bacteria, since these will have been filtered out by the subsoil before the water has found its way into the subterranean reservoir. But when water passes over the surface of the ground, it always takes up some organic matter and along with it some bacteria. These ordinary water bacteria in this case are essential and beneficial, because their work is to assist in the oxidation of the organic matter, and in this manner to purify the water. This was the work the species found in the water taken from the north side of Maiden Creek were doing, and although their number was large, I do not consider their presence prejudicial to the purity of this water. There were no pathogenic bacteria in samples taken from both the north and south sides of the creek, and I consider the supply from this source safe. The case is entirely different with the Antietam Lake and the faucet water. In both, but more especially the former, the bacteria belonging to species which are associated with decaying animal matters were those chiefly found. Most diligent search was made in both waters for the specific bacillus of typhoid fever (the bacillus typhi abdominalis or the bacillus of Eberth-Gaffky), which permeates the intestines and other organs of a typhoid patient, and after leaving the human body is capable of living a considerable time in the water contaminated by the voidings of the invalid. But this specific bacillus was not present in the two samples submitted to me. There were other bacilli present which are almost always associated with the typhoid bacillus, and which have, indeed, been called pseudo-typhoid bacilli, and it has been held by some eminent authorities that when these latter find their way into the alimentary tract, they take on increased virulence under favorable conditions and develop into the true bacillus of typhoid. However that may be, I consider the number and kinds of bacteria found in the Antietam Lake and faucet waters, more especially in connection with the corresponding evidence of the chemical analyses, sufficient to indicate that these waters were dangerously con-

taminated with bacteria capable of producing disease. In the light of the chemical and bacteriological investigations it was recommended that the work of excluding from the drainage area of Antietam Lake all matters of a sewage nature by means of condemnation and purchase of offending properties when necessary, or prohibition wherever mere prohibition would be effectual, should be pushed with great energy. The rights of the municipality in defending the purity of its water supply are paramount, and the legal remedies are adequate to meet every exigency." These recommendations were afterward carried out by the city and the source of contamination done away with and properties purchased.

Maiden Creek Pumping Station.—At this station they use two Worthington pumps, one 5,000,000 gallons and the other and newer 10,000,000 gallons. The water is pumped directly from the creek, 8 miles above Reading, and carried south to Hampden District reservoir, through 11,687 feet of 30-inch pipe and 22,105 feet of 24-inch pipe, against a static head of 208 feet. While it is possible to force 10,000,000 gallons daily through this main, it is considered safer to force 8,000,000 gallons.

STORAGE CAPACITY OF RESERVOIRS.

	Gallons.
Antietam Lake (Ohlinger), storage capacity	100,000,000
Bernhart Reservoir, " "	40,000,000
City Reservoirs, Penn Street, " "	6,200,000
Hampden Reservoir, " "	35,000,000
Egelman Reservoir, " "	2,000,000
Buttonwood Street Reservoir, " "	1,200,000
Total storage capacity	184,400,000

THE DAILY MAXIMUM CAPACITY OF STREAMS SUPPLYING THE CITY BY GRAVITY IN A DRY SEASON.

	Gallons.
Antietam Lake	2,000,000
Bernhart Reservoir	1,368,575
Hampden Springs	80,000
Egelman Springs	100,000
Hampden Drift	16,000
	3,564,575

The daily per capita consumption is about 120 gallons.

Water Supply of Towns below Reading.—The towns between Reading and Philadelphia obtain their water supply from the Schuylkill River. Pottstown formerly pumped from the river below the town, and thus received some surface drainage from the town. This was afterward changed, and the supply is now drawn from above the town. The reservoir is about 1 mile from the river, and has a capacity of 6,000,000 gallons. They have a pump that furnishes 4,500,000 gallons in twenty-four hours. Norristown also obtains a supply from the Schuylkill. There is an island in the river at that point over a mile in length, which divides the river in two parts. The water pipes run under the river and also the island, so that the supply is drawn from the other side of the island, thus avoiding the contamination of Stony Creek, which contains the drainage of the State Insane Asylum. The capacity of the reservoir is 11,000,000 gallons. They have two pumps, a Worthington, which supplies 5,000,000, and a Newbold, which supplies 2,500,000 gallons. The water between Reading and Norristown, a distance of 41 miles, is good as a general rule, because there are few towns between these points; the only two of considerable size are Pottstown and Phœnixville. The amount of drainage that gets into the river between these points can, to a certain extent, be regulated. Between Norristown and Philadelphia, as is well known, the water is not so pure, on account of drainage. It is not necessary to enlarge on this point, as the Lower Schuylkill has been well studied and many analyses have been made.

Fish of the Schuylkill.—The fish commissioners tell us that thirty-three years ago there were no black bass in Pennsylvania. At Harper's Ferry, on the Potomac, were purchased 450 full-sized adult bass; these were deposited in the Delaware near Easton. The writer remembers in 1870, when black bass were first introduced into the Schuylkill; in a few years they became quite abundant and of some importance as a food supply. At that time the red fin, roach and chub were abundant in the river, and the so-called dogfish was common. Many fishermen and some of the fish commissioners have informed me that the red fin is now extinct and the roach and chub

are disappearing. The black bass feed on them. There are many German carp in parts of the Perkiomen and Skippack Creeks; in some places they keep the dams muddy. Among Americans this fish is not regarded with much favor, although it is a favorite food fish in Bohemia. The Delaware, at Trenton, is full of large carp. Near Burlington the carp fisheries furnish Philadelphia and Trenton with nearly a ton of carp per week, consumed mostly by foreigners. The black bass are decreasing in the Schuylkill, owing to the fact that the carp eat their spawn, and also to the fact that the culm or coal dust which comes from the coal region annoys them, as they do not thrive on muddy bottoms. Often after a heavy rain in the coal regions Philadelphia water will be dirty for a week. The greatest amount comes from the Little Schuylkill, although much is dumped along the Big Schuylkill. There was some coal dust dumped along the west side of the Schuylkill between Norristown and Philadelphia which the high water and heavy rains would stir up, but this practice has been stopped.

Dr. Joseph W. Richards, President, in the chair.

Some New Derivatives of Diacetyl.

By Harry F. Keller and Philip Maas.

Since communicating the results obtained in studying the action of oxidizing agents upon diacetyl, we have continued our work on this diketone in several directions.

The ready and quantitative conversion of diacetyl into acetic acid by certain oxidizing agents, notably hydrogen peroxide, induced us to try whether the halogen-substituted products, dibromo-diacetyl and tetrabromo-diacetyl, would behave in an analogous manner. If they, respectively, yielded bromacetic acid and dibromacetic acid, their symmetrical structure might be regarded as definitely established. Thus:

$$CH_2BrCO{\cdot}COCH_2Br + HO{\cdot}OH = 2CH_2Br{\cdot}COOH$$

and

$$CHBr_2CO{\cdot}COCHBr_2 + HO{\cdot}OH = 2CHBr_2{\cdot}COOH$$

While both compounds were found to be readily attacked by the oxidizing agent, only the dibromo-derivative gave something like the expected result.

A weighed quantity of this substance was treated in the cold with a moderate excess of hydrogen peroxide solution. The greasy scales gradually disappeared, and the liquid became strongly acid. Upon evaporating, it gave off hydrobromic acid, and left a residue consisting of a mixture of *bromacetic* and *glycollic* (oxyacetic) acids. This mixture was completely converted into the latter acid by prolonged boiling with water, according to the equation:

$$CH_2Br{\cdot}COOH + H_2O = CH_2(OH){\cdot}COOH + HBr.$$

The characteristic calcium salt was prepared. It was obtained in stellar aggregations of needles, having a silky luster, insoluble in alcohol and only sparingly soluble in cold water. It contained:

	I.	II.	Calculated for $(C_2H_3O_3)_2Ca + 4H^2O$.
Ca	15·06	15·54	15·26
H_2O	26·97	26·47	27·48

The salt is understood to be somewhat efflorescent, and the percentage of water therefore a little too low. The dehydrated salt gave Ca = 21.32 per cent., instead of 21·05 per cent., required by theory.

The blue copper salt was also obtained.

A mixture of several acids is produced when dibromodiacetyl is heated with nitric acid. We have not been able to effect their separation, but have reasons to believe that oxalic acid and monobromacetic acid are amongst them.

When tetrabromodiacetyl was treated with hydrogen peroxide, its yellow color disappeared slowly. A white flocculent precipitate formed while the dense powder dissolved. The colorless solution had a peculiar penetrating odor, and deposited, upon standing, another crop of the product in the

form of long, colorless needles with a silky luster. From 3 to 4 grams of this substance were thus obtained from 10 grams of the diketone.

The mother liquor, still having the characteristic odor of the crystallized product, was extracted with ether, but the latter, on evaporating, left only a small quantity of an oily liquid.

The crystals were found to be insoluble in water, and very freely soluble in alcohol, ether, benzene, glacial acetic acid and other organic solvents. From an ethereal solution very beautiful, prismatic crystals, more than a centimeter long, were obtained. They belong without doubt to the rhombic system, and consist of several prisms, the orthopinacoid and a brachydome. From the solution in acetic acid the substance is reprecipitated in the form of long, fine needles, when much water is added. It melts at 72·8°, and at higher temperatures sublimes, apparently without decomposition.

Analyses of the carefully purified substance yielded:

	I. Per Cent.	II. Per Cent.	Calculated for C_3HBr_5O. Per Cent.
C	8·13	8·04	7·94
H	·56	·26	·22
Br	87·99	88·04	88·30
O	[3·32]	[3·66]	3·53

Determinations of the molecular weight by the cryoscopic method, by means of Beckmann's apparatus and glacial acetic acid as the solvent, gave:

I.

Used solvent	19·485	grams.
Substance	·1788	"
Depression	·084°	

II.

Solvent	19·663	grams.
Substance	·3360	"
Depression	·146°	

I.	II.	Calculated.
461	435	452

The composition and molecular weight correspond to the formula C_3HBr_5O, which is that of *pentabromacetone*. That

this is really the compound we obtained is further proved by a comparison of the physical properties* with those observed by other chemists, as well as its behavior upon boiling with barium hydroxide; *bromoform* was produced and was identified, after distilling it in a current of steam, by its odor and boiling point, and the formation of phenylcarbylamine when the alcoholic solution was treated with aniline and caustic potash.

It is remarkable that an acetone derivative should result from the oxidation of a diketone, for methyl-ethyl ketone can be converted by oxidation into diacetyl.†

The oily product mentioned above, and which was extracted from the solution after the pentabromacetone had separated, may have been tribromacetone. It had a powerful odor, decomposed upon heating, and did not respond to the carbylamine reaction.

Attempts to oxidize tetrabromodiacetyl with nitric acid have not as yet given any definite results. Although the substance dissolves rapidly on warming in the concentrated, especially the red fuming, acid, the greater part of it separates again, on cooling or diluting with water, in large yellow crystals.

Cyanohydrins.—Another class of diacetyl derivatives to which we have lately given some attention, are the cyanohydrins.

Fittig and one of us have shown that diacetyl and hydrocyanic acid unite quantitatively to form a dicyanohydrin, and that this may be readily converted into dimethylracemic acid.

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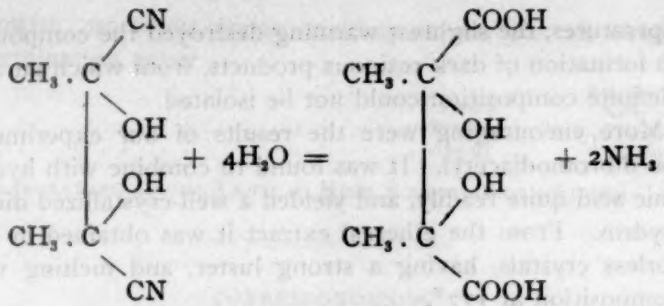
* The melting point is given by Beilstein (3d ed., p. 989) as 76°. Although we repeated the determination several times, using material purified with scrupulous care, and the best thermometers, it invariably gave the same result 72·8°.

† Fileti and Ponzio, *Gazz. chim. ital.*, **25**, 233.



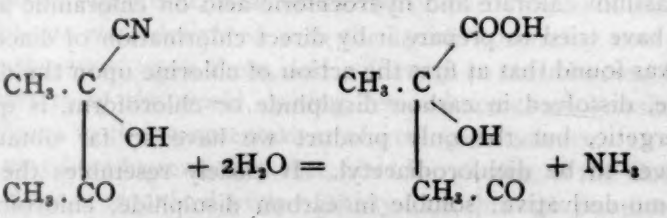
Our recent experiments were undertaken—

(1) To attempt the preparation of a monocyanohydrin of diacetyl.

(2) To produce halogen-substituted cyanohydrins.

If we succeeded in converting the latter into the corresponding acids, we would have the first derivatives of tartaric acid in which hydrogen is replaced by halogen.

Diacetyl and hydrocyanic acid (30 per cent. solution) were brought together in molecular proportions. A rise of temperature and the vanishing of the yellow color indicated that combination was taking place. The liquid was gently heated, and then allowed to stand for some time in a warm place. After extracting with ether, and evaporating this solvent, there remained a colorless, viscous liquid. This was placed over dehydrating materials, and repeatedly cooled to very low temperatures, without showing any signs of crystallizing or congealing. It was doubtless the expected compound, though probably very impure. We now attempted to produce the corresponding acid



by treatment with strong hydrochloric acid. This was tried in a number of ways; but although even the most concentrated acid (saturated at 0°) had no appreciable effect at ordinary

temperatures, the slightest warming destroyed the compound, with formation of dark resinous products, from which an acid of definite composition could not be isolated.

More encouraging were the results of our experiments upon dibromodiacetyl. It was found to combine with hydrocyanic acid quite readily, and yielded a well-crystallized dicyanohydrin. From the ethereal extract it was obtained in fine colorless crystals, having a strong luster, and melting with decomposition at 177°.

Its composition is established by these determinations:

	Found.		Calculated.
	I. Per Cent.	II. Per Cent.	Per Cent.
N	9·38		9·39
Br	54·35	54·74	53·69

The excess of bromine is probably due to the formation of calcium cyanide when the substance is ignited with lime.

Experiments are in progress to transform the nitrile into the acid; the amide of the acid has been obtained in small quantities.

We have also found that tetrabromodiacetyl can be made to combine without difficulty with two molecules of hydrocyanic acid. The resulting body seems to be analogous to the tetrachlorodiacetyl dicyanohydrin described by Levy and Witte.* As yet, however, we have not prepared a sufficient quantity to warrant the publication of definite data.

Dichlorodiacetyl.—As Levy and his pupils† obtained their tetrachlorodiacetyl by a complicated process, the action of potassium chlorate and hydrochloric acid on chloranilic acid, we have tried to prepare it by direct chlorination of diacetyl. It was found that at first the action of chlorine upon the diketone, dissolved in carbon disulphide or chloroform, is quite energetic, but the only product we have so far obtained proves to be dichlorodiacetyl. It closely resembles the dibromo-derivative; soluble in carbon disulphide, chloroform, boiling petroleum ether and warm benzene, it crystallizes in

* *Ann.*, **254**, 98.
† *Ann.*, **249**, 93.

yellowish, unctuous scales, melting at 124·5°. A chlorine determination gave:

	Found. Per Cent.	Required for $C_4H_4Cl_2O$. Per Cent
Cl	45·63	45·80

LABORATORY OF THE CENTRAL HIGH SCHOOL, PHILADELPHIA.

CORRESPONDENCE.

INTERNATIONAL GEOLOGICAL CONGRESS, SEVENTH SESSION, ST. PETERSBURG, 1897.

REPORT OF DR. JOSEPH W. RICHARDS, Delegate of the Institute.

To the President and Members of the Franklin Institute:

Your delegate to the Seventh International Geological Congress, assembled in St. Petersburg at the invitation of the Tsar, respectfully submits the following report:

The Congress was in session from August 29th to September 4th.

Previously to its opening, a number of the delegates participated in an excursion of fourteen days in Esthonia, under the direction of Fr. Schmidt; others in a trip of seven days into Finland, under the direction of I. Sederholm and W. Ramsay; while others, to the number of 120, embraced the opportunity offered to visit the Ural Mountains, and enjoyed an expedition of twenty-nine days in eastern Russia, from Moscow to Ekaterinsbourg and Perm. The members who participated in these expeditions were delighted with the lavish hospitality everywhere showered upon them, and will carry to their homes, in all quarters of the world, lasting remembrances of Russia's friendliness to the representatives of geological science.

It may here be remarked that, after the closing of the Congress, there is organized a trip of thirty days through Southern Russia and the Caucasus (*via* Moscow, Nijni, the Volga, Astrakhan, the Caspian Sea, Petrovsk, Vladi-Kavkaz, Tiflis, Baku, Batoum, Kertch, Sevastopol to Odessa), which will be partici-

pated in by nearly 300 geologists, and promises to be an incident of a lifetime.

On Saturday evening, August 28th, the Committee of Organization gave a reception to the members of the Congress in the rooms of the German Club, where, to the accompaniment of military music, in the comfortable rooms and spacious garden of the club, the assembled geologists renewed old, and laid the foundations of new, friendships. The strenuous efforts of the Committee of Organization to make the days of the Congress pass as pleasantly as possible, may be seen when it is noted that the entire club building, with all its accessories, was rented for the week of the Congress and placed at the disposal of the delegates as a rendezvous.

The formal opening of the Congress took place at 1 o'clock on the afternoon of August 29th, in the large hall of the Zoölogical Museum of the Academy of Sciences, which was beautifully decorated. The scene was a brilliant one, the members and officers being in full dress or uniform, with honors and badges of distinction, the whole scene centering about Their Highnesses the Grand Duke Constantine Constantinovitch and the Princess d'Oldenbourg, who graced the occasion by their presence. The Grand Duke, Honorary President of the Congress, greeted the assembly as follows:*

"In the name of His Majesty, the Emperor, our August Protector, I welcome the brilliant assembly of geologists united here, and I am happy to greet, in you, the representatives of the civilized countries of the entire world.

"It was twenty years ago, on the other side of the ocean, at Philadelphia, that there germinated for the first time the idea of the necessity of concordance in the works of geologists of different parts of the world, and it was decided that the first International Geological Congress would be held in Paris. Even then were plainly evident the series of questions which needed to be solved by the united work of the geologists of all countries. Besides these questions of the first importance, the sessions which have since been held in Bologna, Berlin, London, Washington and Zürich have brought forth a whole series

*The proceedings of the Congress were all held in the French language.

of new questions, of a character equally international, and the solution of several of these has already led to startling results in the whole of contemporary geological literature.

"Since the Congress of London, several of the members had expressed the desire to see the geologists meet in Russia. His Majesty, the Emperor Alexander III, received this wish kindly, and deigned to invite the Congress, then assembled at Washington, to hold its Seventh Session at St. Petersburg. From that time, work has been going on actively to receive in proper manner the members of the Congress. To afford to our guests the possibility of taking note, on the spot, of the geological peculiarities of our country, it was decided from the first that there would be made several long excursions across Russia. This project, however, could not have been realized without the generous assistance of His Majesty, the Emperor Nicholas II. Our gracious Sovereign immediately accorded very large assistance in contributing to the success of these excursions.

"At the present time, many among you, sirs, have already been able to realize part of the projected excursions. A goodly number among you have already twice traversed European Russia and have visited the Asiatic slope of the Urals, that cradle of our mineral industry. You have had, it is true, many difficulties to vanquish in this tour, but I am pleased to believe, sirs, that the privations which you have had to endure have been compensated for by the new and interesting things which you have seen on your journey.

"Others among you have visited Finland, in excursions full of scientific interest, thanks to the enlightened co-operation of our colleagues, the geologists of Finland.

"A certain number, finally, have been able to traverse the Baltic provinces, the coast of Russia, which is, without doubt, the best studied in its geological relations.

"In all your excursions, you have been able to observe the cordial reception which is given in Russia to the representatives of science.

"Now that you have collected new material for your studies, and have seen with your own eyes that which most of

you knew only from the books, you are about to commence the work which is to occupy your attention in St. Petersburg.

"Permit me, sirs, to express the wish that the flourishing tree of geological science, which has already borne such good fruit in the preceding sessions, will not bear in less abundance in the Congress of St. Petersburg, and that our present reunion may give a report of a scientific interest no less satisfactory than those which have been published after each of the previous six sessions.

"I declare the Seventh Session of the International Geologic Congress opened."

After the subsidence of the applause which followed this happy address, Madame, The Princess d'Oldenbourg, President of the Imperial Mineralogical Society, welcomed the Congress in the name of the Society, which was founded under Imperial protection in 1817.

The Grand Duke Alexandre Mikhaïlovitch telegraphed a welcome in the name of the Imperial Society of Naturalists, of which he is President.

The Russian Minister of Agriculture then took the floor, and in a very agreeable manner greeted the assembly, gave a *résumé* of the labors of Russian geologists, noted the intense activity at present shown in all parts of the Empire, especially in Siberia, and declared that: "It is at this moment of ever-increasing development, of even feverish activity, in the domain of geologic science, that we salute as our guests the most eminent geologists of the entire world. This reunion is an event of capital importance, which will leave for all time its trace in the scientific history of our country."

The business of the assembly was then begun. M. Renevier, President of the last session of the Congress, took the floor and announced the recommendations which the Council of the Congress had adopted. The bureau named included, as "Former Honorary President," James Hall, of the United States; as President, Karpinsky, of Russia; as Secretary, Tschernyschew, of Russia; and as Vice-Presidents, thirty distinguished geologists from different countries, among whom were: Marsh, Emerson, Frazer and Emmons from the United

States. The assembly ratifying the recommendations of the Council, M. Renevier resigned the Presidency to M. Karpinsky. The latter took the floor and addressed the Congress at some length. Part of the address was as follows:

"Before beginning our work, I deem it my first duty to render final homage to the memory of the members of former Congresses whom we have had the profound sorrow to lose since our last session. We regret deeply not to see amongst us the Honorary President of the London Congress, Huxley, nor its President, Prestwich; nor the President of the Berlin Congress, Beyrich, nor the illustrious Daubrée. * * * We see no longer amongst us, either, the celebrated Danish savant, Swendstrup, Posepny, the Marquis de Saporta, Bornemann, nor Antonio del Castillo, the founder of the Geological Bureau of Mexico.

"These were all more or less advanced in age, but our science has also lost men full of life and who gave us the brightest hopes. Such were Cope, one of the most illustrious savants of the New World; de Foullon, the worthy Austrian geologist; Leon du Pasquier and Marschal Hall. * * *

"We cannot cite here all the losses we have made; there are many others whom we could name. Let us rise, gentlemen, to honor their memory.

"Passing to the task imposed upon us by our reunion, I would recall to you that the Committee of Organization judges it of the first importance to take up in our session the vital question of the unification of the nomenclature, and that first of all the Congress ought to decide which of the two chronological classifications of sedimentary formations it wishes to preserve in the science, viz.:

"(1) The artificial classification, based solely on historical facts; or

"(2) The natural classification, which is based as much on general physico-geographic changes, common to all the world, as on the knowledge of fauna, and *not* on the accidental limits of diverse divisions called after the name of the country where they have been recognized for the first time.

"Finally, it is desirable that the Congress throw light on a

second question of principle, that of rules to be followed in the introduction of new terms in stratigraphic nomenclature. It is in the highest degree desirable that the Congress, which has already established rules for paleontologic nomenclature, should establish the conditions which authorize the application of new terms to new deposits.

"Another question, of no less absolute necessity, is petrographic nomenclature.

"The development of science ought to be entirely free, without being encumbered by superfluous rules. The remarkable progress made recently in all branches of geologic science has opened up a series of new horizons; these new fields require new terms, which are wanting in scientific language. But, as always happens in such cases, the new terms have multiplied too fast, and never has geology suffered from such a superabundance of new words. We are fast approaching a new Tower of Babel.

"These questions can only be decided by universal agreement among geologists, and no one doubts that the Congress ought to decide them. When nine-tenths or even one-half of the geologists are perfectly in accord upon the necessity of a rule to be followed in order to preserve clearness in scientific language, all the others should finally conform gradually to that rule.

"I cannot close, sirs, without saying that it is a very great pleasure for all us Russians to see assembled in our capital so many geologists of the entire world. That which pleases me, especially (I do not conceal it), is that on returning to your homes you will enlighten your countrymen concerning our country, so little known to most of them. The true geologic science is not confined to one's own country, and it is only the fraternal work of all the geologists of the world which can enlighten us on the structure and evolution of the earth, our great fatherland. This fraternal accord is one of the most beautiful aspects of scientific congresses in general, and in no case can the results be more beneficial than in the progress of the science to which our assembly is consecrated."

M. Karpinsky was succeeded by M. Tschernyschew, Secre-

tary of the Congress, who recapitulated briefly the history of the organization of this Congress. The opening exercises were then closed by the Grand Duke Constantine Constantinovitch.

On Tuesday, August 31st, the Congress visited the Tsar's palace, Peterhof, and was most royally received.

On Wednesday, September 1st, the members were tendered a reception in the Hôtel de Ville, by the Mayor of St. Petersburg and the town council.

On Thursday, September 2d, the Congress was the guest of the Senate of Finland, at the Cascade of Imatra.

The other days were occupied by a sitting of the Council at 9 A.M.; a general assembly for the discussion of general questions at 10.30 A.M., and a meeting for the reading and discussion of papers at 3 P.M. On September 5th, the Congress was formally closed at 1 o'clock P.M., at which sitting the usual votes of thanks were passed, and amid general felicitations, the Congress adjourned to meet next in Paris, in 1900.

The record of the business of the session will be found in detail in the reports sent herewith.

Respectfully submitted,

JOSEPH W. RICHARDS.

ST. PETERSBURG, SEPTEMBER 4, 1897.

NOTES AND COMMENTS.*

WHAT IS ELECTRICITY?

The *American Electrician* condenses from the *London Engineering's* review of Prof. Trowbridge's new book, "What is Electricity?" as follows: The writer says that in spite of the all-round progress made during the last thirty years, we know no more about the essential nature of electricity than did Benjamin Franklin 150 years ago. The several explanations offered, based upon the ether, or ether and matter associated, merely substitute one unknown for another. "After all, what is matter? What is the ether? How is matter associated with the ether? To such fundamental questions we can return no other answer than the now famous ignoramus. They make, or tend to make, us painfully conscious of the infinitude of our nescience." The writer of the review adds that Lord Kelvin must have been brooding over these provoking unknowns when he wrote to him in 1892: "Tell me what electricity is, and I'll tell you all the rest." This inability to detect electricity in its primordial form need, however, exert no distrustful, no depressing

* From the Secretary's monthly reports.

effects on the mind of the student of physical science. "Let him remember that a ray of light is an unexplained phenomenon; yet what wonderful truths are revealed to Fresnel, what knowledge has been wrested from it by means of the spectroscope, and what marvels is it not every day recording on photographic plates! If he feels himself morosely affected by this agnosticism, let him recall the astronomical phenomena which are accurately calculated years in advance without any knowledge whatever of the nature of gravitation; or let him think of that masterly bit of analysis which led to the discovery of argon without any knowledge on the part of Lord Rayleigh or Prof. Ramsay, of what chemical affinity is. If he is a practical man, let him reflect that the engineer lives amid stresses and strains, and though ignoring the intimate nature of the forces which he uses, builds up powerful engines and dynamos, and as successfully tunnels a Mont Cénis as he throws a bridge across the Hudson or the Firth of Forth."

PHOTOGRAPHS WITHOUT LIGHT.

In a recent paper, read by Dr. Russell before the Royal Society, he described the results of a series of experiments which, to photographers, almost rival the discovery of the X-rays. From time to time various experimenters have claimed to obtain photographs by the long exposure of bodies to sensitive photographic surfaces without the action of light. As far as we are aware, however, with the exception of Becquerel's and Colson's experiments, the precautions taken for the exclusion of extraneous light have not been such as to place these experiments above suspicion.

There now seems little room for doubt that many of the common substances with which we are surrounded have the property of emitting invisible active radiations, which can pass through many bodies that we have been in the habit of regarding as opaque. Becquerel some time ago showed that different compounds of uranium, if allowed to remain on a sensitive photographic plate for some days in the dark, had considerable action on the film, and if the plate was developed in the usual way, a photograph of the body was obtained.

Dr. Russell, in repeating Becquerel's experiments, has discovered that this particular action is by no means confined to uranium salts, but that many of the metals and other bodies, such as wood, charcoal, copal, straw, etc., possess it in a marked degree. The radiations from these bodies, however, differ in one very important particular from those given out by the uranium compounds. While the latter readily pass through glass, the former are completely stopped by it. Mr. Colson, in January last, described the action of zinc, cadmium and magnesium on photographic films in the dark. At the time of making his experiments, Dr. Russell was not aware of this, and, consequently, his results are independently confirmed.

Starting with the metals mercury, zinc, magnesium, cadmium, nickel, aluminum, pewter, fusible metal, lead, bismuth, tin, cobalt and antimony, he found that all these, after a week's exposure near a sensitive plate in the dark, produced a distinct effect upon the plate, while gold, iron and copper only showed a very slight effect. The action is not in any way due to "contact phenomena," as a polished surface of zinc with a design scratched on it gave a distinct image of the markings when not touching the plate, and even when thin screens of gutta percha or celluloid were interposed between the sensitive

plate and the zinc surface. Some metals were then coated with copal varnish, to see if this would interfere with the effect. It was found that the image was more rather than less distinct.

In another set of experiments, cardboard pill boxes were used for inclosing certain substances before allowing them to act upon the photographic plate. It was discovered that an empty box emitted active radiations, giving a most distinct image. This suggested experiments with different cardboards, when it was found that the better qualities were quite inactive, while the common varieties, known as straw-board, had considerable action on the plates. Among the other bodies experimented with were green and dry woods, both of which were active. A section from a young larch tree gave an excellent image, showing rings and layer of bark. Charcoal was also found to be active, but lost its activity if heated for several hours in a closed crucible.

The results obtained with printers' ink were very interesting. In many cases they produced no action at all, and in other cases they were remarkably active. The ink used by the *Westminster Gazette*, the *Standard*, and the *Daily Graphic* gave excellent pictures of the printing. The *Times* showed not quite such good results, while ink of the *Morning Post* and the *Echo* had no action at all.

What is this mysterious force? Its nature has still to be discovered. Two points seem to have been established. The first is that an increase of the temperature of the body greatly increases its activity; the second, that aqueous vapor in no way assists the action. Bodies which, at 0° C. had no action whatever, at 70° C. gave distinct images. It has further been suggested that the chemical action is caused by a finely attenuated vapor given on by the different metals and other bodies. It is far more likely to be due to some hidden form of energy more or less akin to what has been paradoxically, but suggestively, called dark light.

THE BOSTON SUBWAY OPEN.

A part of the subway, Boston's new underground thoroughfare for street cars, was open to public traffic the morning of September 1st. The sections to be operated for the present are about three-quarters of a mile long; other sections will probably be opened in the spring. The trip from the public garden entrance to Park Street was made in a little over four minutes; 100,000 people rode through the subway the day that it was opened. The contract for building the last section near the Union Station has been awarded and the work started. The transit commissioners believe that before next summer the entire subway will be in use and Tremont Street wholly free from cars.

METALLURGICAL ITEMS.

The following items of interest are gleaned from the current impressions of the *Engineering and Mining Journal:*

Dr. Borchers, in the *Zeitschrift für Elektrochemie* (June 20th), reviews a new process for winning *phosphorus and calcium carbide from Thomas slag*. In this process tricalcium phosphate is mixed with an excess of powdered carbon, and heated in an electric furnace, whereby calcium carbide, phosphorus and carbonic oxide are formed. The phosphorus passes over into a condenser

and is recovered, the yield being claimed to be 80 per cent. of the theoretical. Dr. Borchers describes a series of experiments made by himself with a view of converting the phosphates of these slags into phosphides, the latter to serve as a deoxidizing material for overblown iron. The results, however, proved negative, the lime in the slag giving off its phosphorus, and going into calcium carbide.——An interesting occurrence of *tin ore and diamonds*, which is, we think, unique, is described in the recently issued report of the Department of Mines and Agriculture of New South Wales for 1896. Gravel containing cassiterite in workable quantity, together with diamonds, was discovered last year at Boggy Camp, fifteen miles west of Tingha, which has been for some time a productive tin field. The pay streak at Boggy Camp, which is from 30 to 50 feet deep, averages from 2 to 7 feet in thickness, the width of the lead not yet having been ascertained. One load of gravel yielded 515 stones of 184 carats aggregate weight, and forty-two loads furnished 600 carats of diamonds, and tin-stone at the rate of 13 pounds per load. The pay streak is a quartz-pebble drift underlying a large hill of basalt. Mr. E. F. Pittman, the Government geologist, who examined the occurrence, considers that the basalt filled what was originally an oval-shaped depression. The gravel rests on granite, and granite can be traced entirely around the basalt. The diamonds are white and of good quality, and it is thought that when the gravel is drained the district will make a considerable production.——At the International Congress for Methods of Testing, at Stockholm, August 23d–25th, Dr. Wedding reported that the proposal to form *an international laboratory for investigating the chemical analysis of iron* had met with warm support in influential quarters, and that liberal annual contributions to its maintenance for ten years had been promised by the Steel Company of Scotland, Consett Iron Works, Sir Bernhard Samuelson, Sir Lowthian Bell, Krupp, of Essen, Cockerill's Steel Works and other Continental firms. The support received was considered by the Congress sufficient to warrant beginning operations, and it was decided to endeavor to open the laboratory by January 1st next, in a building at Zürich, provided for the purpose by the Swiss Government.——E. Piñerúa (*Compes Rend.* 124 pp. 862–863) states that *nickel chloride and aluminum chloride are insoluble in ether*, saturated at a low temperature with hydrochloric acid, while the chlorides of cobalt and of iron dissolve in it readily. The mixed chlorides of nickel, cobalt and iron are dissolved in as little water as possible, a mixture (about 20 c.c. to 0·3 g. of the chlorides) of equal volumes of ether and fuming hydrochloric acid is added, and the whole, in a bath of salt and ice, saturated with hydrochloric acid gas. The nickel separates as a heavy yellow crystalline precipitate, which is washed, first by decantation, and then on the filter, with ether saturated with hydrochloric acid, and then converted into one of the ordinary forms in which nickel is weighed. Cobalt remaining in solution gives a deep-blue color to the liquid, iron a green; small quantities of iron perceptibly change the blue of the cobalt solution; hence this method affords a ready qualitative test for the other metals in reputedly pure salts of cobalt or of nickel. Where much iron is associated with nickel the precipitate retains traces of iron, and should, therefore, after washing, be re-dissolved and re-precipitated. Exactly the same method is pursued to separate cobalt from aluminum. The method gives very exact results.

H. W. Wiley (*Journal American Chemical Society*, 1897, 19, 258–261)

states that the following method has been worked out by K. P. McElroy: The *waste platinum from potash determinations* is collected, dissolved in water, and aluminum in the form of clippings or turnings added to the hot solution. In a few minutes a platinum-aluminum couple is formed, and reduction proceeds vigorously. The addition of hydrochloric acid is advisable to facilitate the deposition of the platinum, and when the reduction is complete, more hydrochloric acid is added to dissolve the excess of aluminum. The spongy platinum is well washed by decantation, and treated with nitric acid to remove any traces of copper; it is again washed, and dissolved in aqua regia (5 parts of hydrochloric to 1 part of nitric acid). The solution thus obtained is evaporated, dilute hydrochloric acid added, and re-evaporated. Should nitrous fumes be evolved on the addition of water, the solution is evaporated, and this treatment continued until the nitric acid is removed. The resulting solution of platinum chloride is then diluted and filtered.—— Siemens & Halske's latest process for the *electrolytic winning of zinc* consists of the treatment of the dry ore (blende or blende mixed with galena) with chlorine gas until chlorination is complete, solution of the chlorides in water, or water to which a little NaCl or HCl has been added, and electrolysis of the solution between an insoluble anode and a metallic cathode, whereby metallic zinc is precipitated and chlorine set free, which is used for the treatment of a fresh lot of ore. Lead goes partly into the solution, but silver remains with the insoluble residue. It is never advisable to carry on the electrolysis so far as to effect complete deposition of the chlorides on account of the cost of the electrical energy; for this reason an excess of chlorine is provided in the solution by the addition of common salt. The undecomposed chlorides are not lost, however, since the nearly spent solution from the electrolytic vats is employed as lixiviant for fresh lots of ore.—— J. R. Mourelo (*Comptes Rendus*, 1897, 124, pp. 1024–1026 and pp. 1521–1523) has experimented with several methods for the preparation of *highly phosphorescent strontium sulphide*, and finds that by far the best results, so far as phosphorescent power of the product is concerned, are obtained as follows: An intimate mixture of 285 g. of commercial strontium carbonate, 62 g. of flowers of sulphur, 4 g. of crystallized sodium carbonate, 2·5 g. of salt, and 0·4 g. of bismuth subnitrate is placed in a crucible, covered with a layer of coarsely powdered starch, and submitted for five hours to a bright red heat, and subsequently allowed to cool very slowly (10–12 hours). A white, friable mass is thus obtained, which develops a fine greenish-blue fluoresence when exposed for about one second to daylight, and so intense as to be plainly visible in a shaded situation. The author remarks, however, in conclusion, that the greater number of his preparations became perfectly inert when powdered, although in some instances the phosphorescent power of the sulphide was restored by re-ignition in contact with starch. While the phosphorescence of calcium sulphide varies considerably in color, with even slight variations in the conditions of its preparation, that of strontium sulphide is remarkably constant, being a more or less greenish-blue. The tint varies slightly, and the intensity to a greater degree, with the source of the sulphide; the most intense and the greenest being that of the sulphide prepared from a mixture of strontium and sodium carbonates, sodium chloride and bismuth subnitrate, while the least intense is the bluer phosphorescence of the sulphide reduced from the sulphate by lampblack.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, October 20, 1897.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 20, 1897.

MR. JOHN BIRKINBINE, President, in the chair.

Present, 78 members and visitors.

Additions to membership since last report, 11.

The President opened the proceedings by giving a brief statement of the pending negotiations between the Institute and the Philadelphia Museums, with the object of holding, in the autumn of 1898, a national exhibition under the joint patronage of the two bodies.

The Secretary reported a vacancy in the Committee on Science and the Arts caused by the resignation of Dr. W. C. Head.

Mr. Arthur Falkenau was elected to the vacant position.

The meeting then proceeded to the business announced on the bulletin, to wit: The consideration of the subject of "Improved Furnaces and Automatic Stokers."

The following inventions were described and shown either with lantern slides or by model, viz.:

The Murphy Automatic Stoker, manufactured by the Murphy Iron Works-Detroit, Mich. Represented by Mr. —— Cotton.

The American Stoker, manufactured by the American Stoker Company, Dayton, O. Represented by Mr. C. H. Bierbaum.

The Acme Stoker, manufactured by the Falls River Rivet and Machine Company, Cuyahoga Falls, O. Represented by Mr. Wm. E. Gray.

The Coxe Mechanical Stoking Furnace, manufactured by the Coxe Iron Manufacturing Company, New York. Represented by Mr. M. C. Jenkins.

The Arndt Econometer, manufactured by Mr. Joseph Wilckes, New York. Represented by Mr. A. Falkenau.

The Hutchinson Smokeless Furnace. Represented by Colonel C. Wolsley Coxe.

The following devices were presented by the Secretary, from written descriptions furnished by the manufacturers, viz.:

The McKenzie Smokeless Furnace, manufactured by the McKenzie Furnace Company, Chicago.

The Black Diamond Smokeless Furnace, manufactured by Bowe & Co., Chicago.

The Columbia Mechanical Stoker, manufactured by the Columbia Stoker Company, Holyoke, Mass.

The Davies Stoker, manufactured by the Davies Stoker Company, Bridgeport, Pa.

At the close of these presentations, the subject was thrown open for general discussion. Messrs. James Christie, Thos. Shaw, Spencer Fullerton and

others participated, and the matter was referred to the Committee on Publications.

The President made an appropriately worded reference to the recent death of Dr. Wm. H. Ford, for many years President of the Bureau of Health of the City of Philadelphia, who had not only been instrumental in securing the reference by the Board of Health of the question of the smoke nuisance as it affects Philadelphia, to the Institute for advice and co-operation, but had also exhibited much personal interest in the discussion of the subject at the Institute meetings during the past few months. The President suggested that some action by the meeting would be fitting as the expression of the sentiment of the Institute, respecting the loss which the city has suffered in the death of a most intelligent and efficient public servant.

It was thereupon voted that the Secretary be directed to record on the minutes of the meeting, the expression of the Institute's appreciation of Dr. Ford's valued service as President of the Board of Health, and its regret at his death.

The Secretary presented the report of Dr. Joseph W. Richards, delegate of the Institute to the Seventh International Congress of Geologists in St. Petersburg. Referred to the Committee on Publications.

Adjourned. WM. H. WAHL, *Secretary.*

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held October 6, 1897.*]

MR. JAMES CHRISTIE in the chair.

Reports on the following subjects passed first reading:

Balanced Locomotive Driving-Wheel, Philip Z. Davis, Philadelphia.

Holophane Globes, George A. Macbeth Company, Pittsburgh, Pa.

Combination Book-Shelf and Book-Support, August Lundberg, Worcester, Mass.

Pneumatic Pyrometer, Uehling, Steinbart Company, Limited, New York.

Reports on the following subjects were adopted:

Testing Machine for Measuring the Intensities of Impulsive Forces.—B. W. Dunn, Lieut. U. S. A., Frankford Arsenal, Philadelphia.

ABSTRACT.—The purpose of this apparatus is to obtain a permanent diagrammatic record of the varying compression produced in a test specimen by a blow, together with an accurate time scale by which the duration of the blow in its component parts can be measured, it having been found that the compression obtained in a static testing machine varies slightly with the time during which pressure is applied.

As these quantities are extremely minute, the record of the Dunn machine is made in magnified form by two rays of light deflected, respectively, by the compression of the test specimen and by the vibration of a tuning-fork, so that they travel over a photographic film carried on the periphery of a rapidly revolving cylinder. The description of this extremely delicate and automatically operating apparatus is not susceptible of intelligible abstract without the use of illustrations. The reader is, therefore, referred to the text of the

report. An approximate notion of its possible utility in the solution of problems outside of the province of the ordnance engineer, may be obtained from the following extract from the report:

"An observer standing in the dark-room and looking toward the revolving cylinder, sees, on its surface, at the instant of impact (*i. e.*, of the test weight on test specimen), a brilliant vertical line of light, whose duration is less than that of a flash of lightning. The photographic film on the rapidly-spinning cylinder, however, has received, in this inconceivably short interval of time, a permanent record of many important events, and arranged them in chronological order, to be examined and studied at our leisure."

The report concludes: "In view of the originality of the investigations made, and of the scope of the apparatus devised by him for measuring the varying intensity of an impulsive force, the award of the John Scott Legacy Medal and Premium is recommended to applicant." [*Sub-Committee.*—L. F. Rondinella, Geo. F. Stradling, Wilfred Lewis, Hugo Bilgram, Luigi D'Auria.]

Process of, and Apparatus for, Manufacturing Mosaics, etc.—Herman C. Mueller, Zanesville, O.

ABSTRACT.—This invention is the subject of U. S. letters-patent, No. 537,703, April 16, 1895, to Herman C. Mueller, and relates to the class of dry-press processes. It consists in part of an improved method of distributing the colored clays for the inlaid designs to the compartments of a suitable frame, by sifting the colored material successively through specially prepared stencils of stiff paper; and in part, of an improved "cell-frame" for holding the body of the colored clays. By means of this improved "cell-frame" and the paper stencils through which the clays are sifted, any design, or part of a design, of large area, falling on a single tile, can be executed without the use of the so-called "cloissonné" or compartment frame, as in previous methods for doing similar work, and the expense of providing work of this class is thus very materially reduced.

The Sub-Committee is unanimous in its belief that Mr. Mueller's invention marks a distinct step in advance in the art to which it relates, and that it offers an admirable means of greatly extending the application of polychromatic decoration in architecture—something of which architecture of the present day is very much in need.

The award of the John Scott Legacy Premium and Medal is recommended. [*Sub-Committee.*—Wm. C. Head, Chairman; Edward S. Morse, W. H. Holmes, Edwin A. Barber, L. W. Miller, Edward Hart, Wm. H. Wahl.]

Arndt's Econometer.—Joseph Wilckes, New York.

ABSTRACT.—This invention is an instrument for measuring the specific gravity of gases, and is especially designed for the continuous measurement and indication of the proportion of carbon dioxide (CO_2) escaping in the flow of the products of combustion of steam-boiler furnaces. It is protected by letters-patent of the U. S., No. 527,397, October 16, 1894, to Max Arndt, of Aix-la-Chapelle, Germany.

The apparatus consists essentially of a balance beam carrying at each extremity a globular glass vessel (both of same volume). Through one of these, by suitable connections, the (dried) furnace gas, taken in a continuous stream from the flue of the furnace, is drawn by means of an aspirator. The other globe is filled with air. The balance is sufficiently delicate to record

the presence of very small proportions of carbon dioxide in the flue gases, the percentages of same being indicated continuously by the pointer of the balance passing over a graduated scale. The details of the apparatus must be sought for in the report.

The tests of the Sub-Committee with one of these instruments in service at the Baldwin Locomotive Works, in this city, were highly satisfactory, and showed that its indications did not vary appreciably from those obtained by chemical analysis.

The report finds that the claims of the applicant were fully substantiated.

The award of the Elliott Cresson Medal is recommended to the inventor. [*Sub-Committee.*—Wm. M. Barr, Chairman; Arthur Falkenau.]

Improvements in Vehicle Wheels.—E. L. Markley, Royersford, Pa.

ABSTRACT.—This invention relates to an improvement in vehicle wheels, covered by U. S. letters-patent No. 569,703, October 2, 1896, to George P. Yeakel.

The improvement consists essentially of a tire made in two parts, a thin inner strip, called by applicant the plate; and the outer part, or tire proper, which may be flat on the outside, where there is only the steel tire, or recessed for carrying a rubber tire. The plate is rolled with a channel in the center, correspondingly projecting on the other side, which is the outside, with its edges turned into flanges embracing the rim, which flanges are partly turned before the plate is put on the wheel. The tire proper is rolled with a channel on the inside corresponding to the projection on the plate.

In putting on the tire, the plate is bent approximately to the shape and size of the wheel, and the tire proper having been heated, is shrunk on over it, compressing it closely on the wheel.

After the tire has been so shrunk on, the plate is pressed between rollers, which complete the flanging, pressing the flanges into the rim. The plate is held in place on the rim by the flanges, and the tire proper on the plate by the corresponding projection and channel. The joints of the rim are further held together by a short bar, sunk into the rim on the outside, in which is a bolt holding a clip on the inside. No tire-bolts are used.

Comparative experiments, made under the Sub-Committee's direction, on wagons similar in all respects and doing the same work—one being furnished a set of these tires and the others having ordinary tires, failed to show any superiority in the Yeakel tires over those in common use. [*Sub-Committee.*—G. M. Eldridge, chairman; H. R. Heyl, Spencer Fullerton.]

Investigations in the Molecular Physics of Cast Iron.—A. E. Outerbridge, Jr., Philadelphia.

ABSTRACT.—The scope and general character of Mr. Outerbridge's observations and studies of the molecular changes taking place in cast iron under the influence of continued vibration have already been set forth *in extenso* in the JOURNAL, and need not, therefore, be repeated.

The Sub-Committee confirmed the correctness of these observations and inferences by a series of experiments conducted in the foundry of the Camden Iron Works, the results of which are appended to the report.

The Sub-Committee's opinion of the merits of this work is concisely stated in the following extract from the report:

The fact that a certain molecular change takes place in cast iron in the

course of time, has been known and recognized for a long time, and that this change tends to relieve the internal strains and render the casting tougher, has often been noticed and acted on, although in a very crude way; but so far as the Sub-Committee has been able to learn, Mr. Outerbridge was the first to make a careful study of this and to note that the change may be hastened by impact, and the maximum strengthening effect produced in a short time, and also to make a scientific study of the phenomenon. Great credit is due to Mr. Outerbridge for the initial observation and the careful work dependent thereon. The results of his studies, given for the first time at the meeting of the American Institute of Mining Engineers (February 20, 1896), have since attracted wide-spread interest and discussion, but nothing growing out of this has shown that any one either in this country or abroad, has anticipated Mr. Outerbridge in this work.

The John Scott Legacy Premium and Medal is recommended. [*Sub-Committee.*—C. J. Prince, chairman; Wm. C. Henderson, Wm. R. Webster, Gus. Henning.]

SECTIONS.

CHEMICAL SECTION.—*Stated Meeting*, September 21, Dr. Lee K. Frankel, Vice-President, in the chair.

Dr. Harry F. Keller presented a communication on "Some Derivatives of Diacetyl."

Prof. O. C. S. Carter read a paper on "The Upper Schuylkill," devoted specially to a consideration of the nature and causes of the impurities in the upper river waters, and the influence by which the same are neutralized by natural causes.

Stated Meeting, October 19th, Dr. Frankel in the chair. Dr. Keller made some "Remarks on the Analysis of Electrolytic Copper." Mr. Philip Maas made a communication on the "Composition of Certain Vanadium Minerals from Leadville, Col." Dr. Wahl exhibited specimens of magnesia fused in the electric furnace; also specimens of steel-lined aluminum culinary ware.

MINING AND METALLURGICAL SECTION.—*Stated Meeting*, October 13, Mr. Benj. Smith Lyman, President, in the chair. The following communications were presented: "Some Remarks on Wired Glass," by Francis Schumann. "The Econometer and Specific Gravity Apparatus, for Automatically Indicating the Condition of Combustion in Furnaces," by Arthur Falkenau. "Copper Traces in Bucks and Montgomery Counties," by Benj. Smith Lyman. Dr. Wahl described and showed in operation the Burton Electric Liquid Forge.